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SCIENCE AND THE PLANNED STATE

By the Same Author

THE SCIENTIFIC LIFE

With J. B. S. HALDANE

BIOLOGY IN EVERYDAY LIFE

SCIENCE
and the
PLANNED STATE

by

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Preface

IN a sense this book is a sequel to *The Scientific Life*, which was published in 1942. Care has been taken to make it equally suitable for those who have read the earlier volume and those who have not. There is very little repetition, though I have once more insisted on the importance of chance in scientific discovery. The main purpose of *The Scientific Life* was to describe the human nature of the good research worker, and to show that it would be futile to try to confine him within the rigid boundaries of a central plan for the advancement of science. Both books are meant for scientist and layman alike, including the older students at schools, and both are lightly written; but this new book is much the more systematic in treatment. It consists of a careful analysis and criticism of the totalitarian view of science, of which so much has been heard in recent years.

It is a great pleasure to acknowledge the help given me by my wife and my friends, especially Dr C. P. Blacker, M.C., F.R.C.P., Professor V. H. Blackman, F.R.S., Professor E. S. Goodrich, F.R.S., Professor M. Polanyi, F.R.S., and Professor A. G. Tansley, F.R.S. Professor Blackman has read the whole book and the others have read parts of it, and all have made valuable suggestions.* Even more valuable has been their encouragement, for the book is in conflict with a social outlook that has much popular support to-day. The person who wants to be comfortably reassured in the beliefs current in our newspapers will find little to his liking in these pages. I address myself to the boy or girl, man or woman who has the courage and independence to think for himself or herself and to question the validity of popular opinion.

* It is not implied that all the friends mentioned agree with every statement in the parts of the book they have read.

Chapter II is an expansion of an address delivered to International Student Service, and parts of Chapters IV and V contain material presented in a lecture to the Institute of Physics. I thank I.S.S. and the Institute for permission to publish this version of what I said.

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Postscript

In the first printing of this book I quoted the following statement of Mr David Low, the cartoonist: "Understand, we are not here to pass honest judgments but to purvey matter the other side doesn't like." [68] Mr Low assures me that this statement was ironical and expresses the opposite of his real opinion. I apologize to Mr Low for not realizing that his words were used ironically.

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Chapter I

INTRODUCTION

1. *The Story of John Ellis, Merchant and Naturalist*

JOHN ELLIS, London merchant, had a most unusual hobby. He received seaweeds from collectors on the Welsh and Irish coasts. "These, when properly dried, I disposed on thin Boards covered with clean white Paper, in such a manner as to form a kind of Landscape, making use of two or three Sorts of the *Ulva marina*, or Sea-Liverwort of different Colours, in designing a Variety of Hills, Dales, and Rocks, which made a proper Ground-work and Keeping for the little Trees, which the expanded Sea-plants and Corallines not unaptly represented." [27]

A friend expressed pleasure in viewing these landscapes and encouraged him to make some for the royal family, so that with the aid of examples the young princesses might try the new art for themselves. The landscapes were accepted with royal condescension, though there is no evidence that anyone has ever copied them during the space of nearly two centuries which separates us from these events.

To supply the princesses in a fashion that would accord with their exalted rank, Ellis undertook a large collection of marine plant and plant-like productions. He soon began to want to classify them in a natural way. He turned at first to the system of the illustrious Ray, but discovered that the latter had erred in attributing them all to the vegetable kingdom. Ellis found it necessary to use a simple microscope, and it was not long before he discovered that in many of them the "Texture was such, as seemed to indicate their being more of an animal, than vegetable Nature." Soon he "was convinced, from my own Observations of the Subjects themselves, that several, which had hitherto been considered by Naturalists, as Marine Vegetables, were in Reality of animal Production."

Ellis was now like a hound on hot scent. He undertook visits to the coasts, accompanied by artists who drew what they saw through "a very commodious Microscope." Very remarkable were the organisms that his commodious instrument presented to their view, and remarkably accurate and beautiful their drawings. Without in the least minimizing the previous studies of Jean-André Peyssonnel in the Mediterranean, of Abraham Trembley in Holland, or of Bernard de Jussieu on the coasts of France, it may justly be claimed that Ellis, more than any other single man, caused scientists to accept into the animal kingdom the great and diverse groups of hydroids, sea-fans and their allies, and Polyzoa. No other man has ever made so great an enlargement of the subject-matter of zoology.

His contemporaries were not slow to acknowledge the services to science of this gifted amateur, whose investigations had had such an unpredictable beginning. His *Essay towards a Natural History of the Corallines* [27] was published in 1755, and by 1768 he was not only a Fellow of the Royal Society, but had received from its President the Copley Medal and an enthusiastic address of congratulation. These encouragements made Ellis even "more anxious in the pursuit of his favourite study."

Like many investigators of nature, Ellis pursued science as an end in itself and was also interested in its applications. His best work was purely scientific, but he also did much to apply botanical knowledge to practical human affairs. He published accounts of the mangosteen, breadfruit, and other plants, with directions for conveying seeds and seedlings to distant parts of the world to promote the purposes of medicine, agriculture, and commerce. His historical account of coffee, published in 1774, was intended to increase the consumption of that article and thus help the planters in the West Indies. So it was written of him, "And his active mind was constantly employed in devising means for promoting the welfare of society until the time of his death, which happened on the 15th of October 1776."[28]

These activities had their influence on contemporary society, but Ellis is remembered to-day almost entirely for his purely scientific work. He was intensely interested in plant-like animals, and he wanted to share his interest with others. That is how he regarded the social aspect of science, apart from its applications. He said so in no uncertain terms. "And now," he wrote, "should it be asked, granting all this [about plant-like animals] to be true, to what end has so much labour been bestowed in this demonstration? I can only answer, that as to me these disquisitions have opened new scenes of wonder and astonishment, in contemplating how variously, how extensively life is distributed through the universe of things: so it is possible, that the facts here related, and these instances of nature animated in a part hitherto unsuspected, may excite the like pleasing ideas in others." [28]

2. *Definitions*

I have started by relating the story of John Ellis because it is in such sharp conflict with the totalitarian view of science and thus makes our subject vivid. The story brings home a fact about science which could be illustrated less strikingly but equally truly from the personal experience of many investigators, great and small—the fact that scientific discovery is often prompted by extraordinary and unpredictable circumstances apart from the material needs of man. These needs are served by science, but the promptings of many investigators are neither economic nor materialistic. Szent-Györgyi, who was awarded the Nobel Prize for Medicine, has made some forcible remarks bearing directly on this subject. "The results of my own scientific activity," he says, "have restored many men to life and health and preserved others from illness, and therefore I have often been praised for my goodness. When I hear this I cannot help smiling." [98] He goes on to say that "the man who sets out to work intending to discover something useful" should actually be excluded

from the laboratory. He remarks that every real discoverer "was spurred on by an inner passion and impulse."

We are faced to-day by a considerable body of propaganda intended to make us view science in a light which Ellis would not have understood. We are told that the science of any given period is the inevitable result of political and economic conditions. The scientist may think that he is guided by his interests, but actually his studies are determined by material forces beyond his control. This theory forms part of the materialist view of science, accepted by the rulers of totalitarian states. It is the purpose of this book to examine the materialist or totalitarian view.

It is necessary at the outset to be sure about what will be meant by certain constantly recurring words.

It is sometimes said that there is no such thing as pure science. This is an argument about the meanings of words, not about facts or opinions. On the one hand there is an organized body of general demonstrable knowledge about the matter of the universe. Students of this body of knowledge unhesitatingly recognize a hierarchy of importance among its parts, according to the amount of light they throw on other parts and the degree in which they are capable of being comprehended under generalizations. On the other hand there is a second body of knowledge which codifies the applications of part of the first body of knowledge to material human welfare and also includes many demonstrable facts that are used to supply the material wants of man but not to throw light on other facts nor to support generalizations. The distinction between the two bodies of knowledge is so necessary and obvious that even those who deny it nevertheless find it necessary to draw it in their writings. They may try to get over the difficulty by writing "pure" science, with pure in inverted commas, or by various circumlocutions, but they know that a distinction exists.

There is no reason why a generalization, capable of linking facts not previously known to be related, should be materially

beneficial to man. Similarly, to say that every demonstrable discovery will be used in a practical way before the inevitable extinction of mankind is to make a prophecy that is without any foundation. Again, there are technical processes of material benefit to man which are not understood, and have not thrown light on other facts. Two bodies of knowledge exist, which differ although they overlap. In the one, the best is what is most enlightening: in the other, the best is what works best.

If it be wished to avoid all purely linguistic arguments, the first body of knowledge may be called a and the second b. Anyone who wishes to group the two under a single title is at liberty to say that $a+b=c$. Words, however, are better than symbols, because more easily remembered, and *science* is a convenient word for a and *technology* for b. It is an unfortunate fact that the convenience of words as compared with symbols makes people quarrel over words when they think they are quarrelling over facts or opinions about facts. Thus, when a is called science, it is argued that it is presumptuous to confine the meaning of this word to only a part of c. Again, when a is called pure science, it is queried whether b is impure or tainted. This query was raised repeatedly by different speakers at the meeting of the British Association held at the Royal Institution, London, in September 1941. Such talk is not argument, but only a ridiculous kind of playing with words. In this book, *science* will be used for a and *technology* for b purely as labels, not as arguments about anyone's opinion as to the value of the thing named. Technology is the knowledge of techniques which serve man's material wants. It consists partly of the applications of science, and partly of empirical and rule-of-thumb knowledge about isolated facts.

While we are on the subject of words, it may be remarked that the person who cultivates science is a *scientist*. A curious opposition has arisen to the use of this convenient word, and multisyllabic substitutes are sometimes preferred. People who would blush to use the expressions *men of music* or *musical*

men do not hesitate to write *men of science* or *scientific men* when they mean scientists. This post-prandial pomposity is best relegated to the environment of the white tie and tail-coat. It is true that the expression "Men of Scyence" is to be found in a sixteenth-century writing, but the context suggests that it was then applied to technologists. The term *scientific workers*, again, is three syllables too long, and although not so obnoxious as the others, yet lends itself to use by those who would surreptitiously insinuate some special bond of unity between scientist and factory-worker.

Though I have lived a quarter of a century in scientific circles, and seen men of science and scientific men and scientific workers tumbling over one another in print, I do not recollect ever having heard any of these expressions used in conversation (except when *The Scientific Worker* was used as the name of a journal). The word always or almost always used in conversation is *scientist*. We owe that word to the Rev. William Whewell, Professor of Moral Philosophy in the University of Cambridge. Few deliberately invented words have gained such wide currency, and many people will probably be surprised to learn that it is only just over a century old. Whewell undertook the invention of the word in no light spirit. His "Aphorisms concerning the Language of Science" cover more than seventy pages of *The Philosophy of the Inductive Sciences*.[109] The "Aphorisms" constitute a careful inquiry into the ways in which new words are and should be constructed. He observes that the terminations *ize*, *ism*, and *ist* are applied to words of all origins. Forthwith he coins the universally accepted *physicist*, remarking that *physician* cannot be used in this sense. He proceeds at once to the invention of an even more necessary word. "We need very much a name to describe a cultivator of science in general.* I should incline to call him a *Scientist*." So should I.

So much for the words *science* and *scientist*: now for *totalita-*

* The context makes it clear that Whewell did not restrict the name scientist to those whose interests cover the whole subject.

rianism. This ugly mouthful has unfortunately no euphonious synonym. The word had gained general currency as a comprehensive name for the political systems of Germany, Italy, and the U.S.S.R., when Hitler's invasion of Russia made the astute editors of our daily and weekly Press recognize that it might be inept to bracket our new allies with our old enemies. The word was dropped like a hot brick. It has cooled too long and I pick it up without hesitation. By totalitarianism I mean those systems of government in which the actions of individuals are to a great extent controlled by a central planning authority. It is the antithesis of anarchy, but as that is a system which no country has ever adopted, the most exact opposite in the world of reality is liberalism. It is strange to reflect that there is so little memory to-day of what liberalism stands for, that the man in the street thinks of it as intermediate between socialism and conservatism. This idea is misleading. If we wish to arrange the various political systems in linear order, it may be suggested that liberalism should be placed beyond, not between, socialism and conservatism. At one pole come the totalitarian systems (nazism, fascism, and communism), in which the state is all-powerful and ruthless and the individual deprived of liberty. Next come socialism (in the narrower sense) and conservatism, under both of which the state has great power but avoids ruthlessness and allows some liberties to individuals. At the opposite pole to totalitarianism stands liberalism, the system which puts the liberty of the individual above all else and regards the state merely as a mechanism for minimizing people's interference with one another's freedom. It is in this sense, as the antithesis to individual liberty, that the word totalitarianism is used in this book.

3. *The Case for Totalitarianism in Science*

The scientist, like all other members of the community, has rights and responsibilities. The rights are the conditions

which the community must grant to him if he is to be able to perform his function effectively. If he is a teacher, these rights resemble those of all teachers and do not call for special comment here. If he is a research worker, they call for a lot of comment. The history of science and the experience of modern research suggest that the investigator's rights, above everything else, are four kinds of freedom: freedom to become a research worker, freedom of association, freedom of inquiry, and freedom of speech and publication. Most of these freedoms have been lost in totalitarian countries, and the ever-growing movement towards central planning threatens them in Britain.

Balancing the scientist's rights are his responsibilities. There are, of course, obvious duties, which differ according to the nature of the function which the scientist is fulfilling. If he is a teacher of science at school or university, a primary duty is clearly to teach science to the best of his ability and imbue his pupils with its spirit. If he is a research worker, his duty is naturally to make the greatest possible contribution to demonstrable knowledge. Many members of the staffs of universities are both teachers and research workers and thus have both these duties. There exists also a wide field of further opportunity to repay the community for its grant of the freedoms that enable the scientist to live a full life and exploit his talent. These opportunities are open to all scientists, whether students or teachers or research workers.

A lot of trouble has been taken to tell scientists what their responsibilities are. Large volumes have been written and addresses given to considerable congregations. Nevertheless, it is not easy to find a formal statement of the obligations of the scientist to the community, as laid down by our modern scientific moralists. It is therefore necessary to try to condense the message into a form in which it can be examined. It seems to be divisible into three propositions:

(1) Science exists to serve the material wants of man.

(2) Central planning makes for efficiency, and scientists have a duty to press for its introduction in their own sphere. Not only would overlapping be avoided, but trivial investigations would no longer take up time and money. The central authority would know the material wants of the community, and would be able to direct the course of research in such a way as to relieve these wants as speedily and economically as possible. Teams of research workers would be available to be switched quickly on to the most pressing need of the day.

(3) Since scientists are accustomed to do everything methodically, and since they must recognize that central planning would improve the efficiency of their own work, they should press for the adoption of a scientific scheme of central planning in all departments of life. "Logically," says Bukharin, "Marxism is a scientific system, a scientific outlook and scientific practice." [14] Scientists have been irresponsible, supporting any political party or none, as though they had no serious concern with the welfare of others. It is their duty to take an interest in party politics and to support the side that promises to introduce a policy of central planning under state control. It will also be to their own advantage to ally themselves with the party that will gain power.

The purpose of this book is to consider these three propositions. When they are stated like this, in moderate terms, a case is presented which calls for careful consideration. Those who have brought the arguments forward in moderate form have performed a useful service by making scientists reflect seriously about their social obligations. Nevertheless, the arguments are sometimes stated in an immoderate form which

is not only not helpful, but positively threatening. It is important that scientists should understand clearly how extreme are the views of some of those who profess to teach ethical principles to scientists. These views are available in print, but are not generally known. It is desirable that scientists who are influenced by arguments about their morals should understand clearly what ideas influence the extreme wing of their ethical authority. They can find out easily enough by referring to Mr J. G. Crowther's book *The Social Relations of Science*, published in 1941 by Messrs Macmillan.[19]

Mr Crowther is of opinion that scientists should attach themselves to certain particular political groups. The use of persuasive argument is not thought likely to suffice, for Mr Crowther says quite unequivocally that under some circumstances the use of inquisition is desirable. "Inquisition is beneficial to science," he says (p. 333), "when it protects a rising class." The reader should refer to the book itself, so that he may not be under any misapprehension as to what Mr Crowther means. He means that the methods of the Inquisition of ancient times should be reintroduced to make sure that people shall accept political views in accord with his own. "Those who have revived the Inquisition, like the Pope in Galileo's time," he writes (p. 331), "have a better understanding of politics [than most scientists of to-day], and realize that in crises the possession of power is more important than the cultivation of intellectual freedom. . . . The danger and value of an Inquisition depend on whether it is used in behalf of a reactionary or a progressive governing class." A "progressive governing class," in fact, is right in using the methods of the Inquisition, and scientists would be well advised to get on the safe side in politics. Mr Crowther does not find fault with authority for its treatment of Galileo, nor with that great scientist for recanting when threatened with torture, but only blames Galileo (p. 333) for not "seeking the protection of progressive powers, who will fight for him as well as argue, if necessary."

The reader may be inclined to minimize the influence of Mr J. G. Crowther in the scientific world. That would be a mistake. He is the secretary of the scientific section of the British Council, and thus in charge of the representation of British science before the world. The extreme section of opinion is unquestionably influential.

Nothing less than a realization of the gravity of the situation would induce me to copy those with whom I disagree by ascending the pulpit. Some one, however, has got to do it. Opinion is inevitably formed if all the talking and writing come from one side. Only one point of view is being presented as to the moral obligations of scientists. That point of view leads by insensible steps to the conclusion that scientists should be subjected to inquisition to secure conformity with political dogmas. By a twisting of the English language a policy that involves reversion to the cruelties of the Middle Ages is presented as the course of progress.

The purpose of this book is to suggest that progress lies in another direction. The design is as follows. Chapter II will be devoted to a consideration of the argument that science exists only to serve the material wants of man, upon which the whole of the totalitarian view of science is based. The freedoms which serve best the cause of discovery will be discussed in Chapter III. Chapter IV will provide an actual example of what happens to science when these freedoms are denied. So much for the rights of scientists: the last Chapter will be concerned with their duties and responsibilities, and a general survey will be given of the ways in which they may use their special talents for the benefit of others.

Chapter II

THE VALUES OF SCIENCE

"Other interests, besides the material wants of life, occupy the minds of men."—A. VON HUMBOLDT.[50]

1. *Grades of Opinion on the Values of Science*

THAT scientific knowledge can be applied to the material welfare of man is so obvious that no discussion of this value of science is necessary. Those who think that science has other values do not minimize its contributions to the feeding of human beings and their protection from the elements and from ill-health. There are those, however, who deny that science has any value apart from these contributions to material welfare. Four grades may be distinguished in the scale of opinion, as follows:

(1) Science has value only in serving the material wants of man. The only consideration is the material welfare of the community as a whole. This is the extreme totalitarian position.

(2) Science has value only in serving the material wants of man, but research workers do their best work if they enjoy it.

(3) Science has value both in serving the material wants of man, and also in enabling people to escape from certain mental evils. The study of science prevents unhappiness consequent on pettiness of outlook, and produces forgetfulness of unpleasant memories. This rather negative position is that of Bertrand Russell.[91]

(4) Science has another value besides serving the material wants of man and enabling people to escape certain mental evils. It has a positive primary value as an end in itself, like music, art, and literature.

In the past there also existed a fifth opinion, held by those who were actually glad when they thought that certain scientific discoveries could not be used to serve the material wants of man. This opinion scarcely exists to-day and seems not to merit further consideration.

2. *Scientists do not work only for Material Ends*

There is not any necessary connexion between the material usefulness and intrinsic interest of a scientific discovery. "We can declare without the least hesitation," says Szent-Györgyi, the famous biochemist, "that to judge scientific research by its usefulness is simply to kill it. Science aims at knowledge, not utility." [98] It is extremely unlikely that every discovery will serve man in a material way before the inevitable extinction of human life. Some of the most profound truths will probably not be used practically. Professor G. H. Hardy [43] has made this point neatly for mathematics. He cites some easily understood mathematical proofs, whose beauty and general significance are apparent to everyone who follows them. Having won the reader's willing assent to their value, he goes on to prove that they not only are not, but cannot be used by the practical man. Euclid's proof that the number of prime numbers is infinite is so masterly and economical that everyone who follows it, mathematician or not, acclaims its value; but as Professor Hardy points out, it is more than sufficient for the engineer to know that the number of primes less than 1,000 million is 50,847,478, for practical men never work to more significant figures than this. In science we can never say that a discovery will never be used to promote material welfare, but we can and must say that scientists are interested in discoveries apart from the possibility of their producing food, shelter, health, etc.

The pretence that science only serves humanity by giving us food, health, and shelter leads to nonsense; for it means that we live only for food, health, and shelter, instead of

requiring them so as to live for something else. Why do we feed and protect ourselves and others? Is it so that we and they may live to feed and protect others, so that they may do the same for yet others, and so on interminably and senselessly? "Have we nothing eventually in view more admirable than the abolition of want and the securing of comfort for everyone, ends which at present bulk so large in our programs?" The question is put by the distinguished American physicist, Professor P. W. Bridgman. "Will we be permanently satisfied with these, or will something more be necessary to give dignity and worth to human activity?" [12]

There must be something else for which people want to live. Great music, art, and imaginative literature, it may be suggested, are examples of valid ends. If a scientist makes that answer, it is necessary for him to say that he practises science so that the applications of what he discovers may keep people alive, so that they may appreciate music, art, and literature, which are the real ends in life which make him practise science. This house-that-Jack-built rigmarole is nonsense. The scientist may indeed value these subjects highly, and they are certainly ends in themselves; but if his dominant impulse were not scientific he would be a poor scientist. Science is as much an end in itself as music or art or literature. ". . . if ever there are ends in themselves or goods in themselves," Professor Bridgman has written, "then surely the gratification of the craving for understanding is one of them." [12]

People engaged in practical pursuits have often advanced science, and this fact is sometimes made the basis of a claim that science had its origin in a desire to satisfy the material wants of ordinary human life. From that premiss it is argued that scientists should devote themselves to the satisfaction of those wants. Even if the claim were justified, the conclusion could not be logically deduced from it; but the claim itself is not justifiable. We cannot know anything for certain about the earliest beginnings of science, but we do know that modern savages are interested in natural objects and

phenomena apart from their material usefulness. Science as we know it to-day may be said to have originated about the eighteenth century, for although there were scientific geniuses before then, the spirit of the subject was confined to a small number of people, and their discoveries were somewhat isolated. During that century there was a wonderful blossoming forth of science. Magnificent work was done, especially in biology. The best of that work was inspired by nothing but an intense desire for knowledge for its own sake.

The scientist of to-day is often cynically indifferent to the early history of his subject. He knows that people used to make fantastic concoctions intended to cure human ailments, and he recognizes no connexion between such activities and his own. He is right, but he has missed the point. The men who were struggling solely to give practical help to mankind often made little or no contribution to knowledge; but those who had an intense desire for knowledge for its own sake were doing research that is comparable with the very best that is being done to-day.

Just over two centuries ago Réaumur [88] published a memoir on the reproduction of aphids and Trembley [102] a book on the natural history and response to experimental procedures of the little fresh-water polyp, *Hydra*. I challenge anyone who is cynical about old-time science to point out any modern work that provides a better example of scientific method than those studies of Réaumur and Trembley. Réaumur's memoir was devoted to the question whether aphids can reproduce without sexual union. The way in which he tackled this question, in free collaboration with Bonnet, Bazin, Trembley, and Lyonet, provides an example to be copied by modern scientists. The clear introductory statement of what was already surmised on the subject, the scrupulous care and accuracy of the work, the elaborate attention to detail, the unwillingness to accept anything without stringent proof, the avoidance of unnecessary hypotheses—all these are models for all time. Réaumur and his friends established beyond question

that aphids can reproduce without sexual union. Trembley's book on *Hydra* is, of course, a classic. It contains not only an excellent description of the form and natural history of the various species, but also a full account of the studies on regeneration, which may be said to mark the origin of experimental zoology. Indeed, these experiments are quoted in modern text-books, not as historical curiosities, but as our best information on the subject. Trembley's description of how he turned the minute organism inside out and how it survived this extraordinary operation was for long disbelieved; but recently Mr R. L. Roudabush [89] has succeeded in repeating Trembley's experiment and confirmed the survival of the reversed animals. The whole of Trembley's book, like Réaumur's memoir, is a model of scientific method. *In neither is there any indication that the author was striving to satisfy the material wants of man.* Their spirit was that which has been the chief animating influence of science ever since.

The scientist of to-day often opens a text-book and takes what he reads there as though it had arrived on those pages as a matter of course. What an eye-opener it would be if he could glimpse, even vaguely, the history of the knowledge contained in a single sentence chosen at random! Even if the sentence dealt with a modern subject, its history would go far back along the ages; and he would see a succession of the men who brought the knowledge contained in it into being. They were not just names in a history-book of science: they were real, live people, diverse in many ways, but nearly all united in belief in the value of science as an end in itself.

3. *The Borderland between the Material and Immaterial Values of Science*

There are certain values of science which stand half-way between the crudely material values on the one hand and the immaterial values on the other. Knowledge of the facts of equal inheritance from both parents (apart from the genes

borne on the sex-chromosomes) is important in framing people's general social outlook, but it does not directly provide them with food, health, or shelter. The relative status of man and woman would be different from what it is if people believed that inheritance were wholly maternal (as the Trobriand Islanders, for instance, are said to believe) or wholly paternal (as some biologists once thought). Again, people's social outlook is affected by their beliefs on the scientific question whether what are popularly called "acquired characters" are inherited. The function of science in reducing superstition comes into this category of values.

4. *The Appreciation of Science as an End in Itself*

We must now analyse the immaterial or spiritual values of science.

The history of science suggests that many great investigators have accepted the value of science as an end in itself as something so obvious as not to require analysis. Einstein has well expressed what are probably the inarticulate feelings of many people who value science as an end. "The satisfaction of physical needs," he writes, "is indeed the indispensable precondition of a satisfactory existence, but in itself it is not enough. In order to be content, men must also have the possibility of developing their intellectual and artistic powers to whatever extent accords with their personal characteristics and abilities."

There are reasons for thinking that science is potentially the greatest achievement of the human mind. Optimists may look for that greatest achievement in ethical perfection. They may be right and I hope they are; but life among savages has shown me that if civilization and religion have improved men morally, then the improvement that has occurred has been too small to give reason for much optimism about the future. In most intellectual fields we cannot look forward with confidence of progress. There is no reason to suppose that the historians of the future will tower above those of the present

day. Philosophy has given the world some of its greatest geniuses, but the history of the subject contradicts the idea of a gradual approximation towards a consensus of opinion on philosophical subjects. We cannot guess the future of music, but at least it may be said that the world to-day has no composer who will bear comparison with the geniuses of the past. It is sometimes argued that geniuses are not recognized in their own times, and that we may even now have a genius of musical composition in our midst; but the fallacy of this argument is apparent to anyone who is acquainted with the history of music. The same considerations apply to pictorial art, and there is no sure ground for thinking that we are merely experiencing a phase of relative inactivity which will be followed by a new outburst of progress. In science, on the contrary, the present state of affairs and the prospect for the future are both very good. The standard of excellence is as high as ever it was. We have genius to rank with the greatest of all time (in physics alone we have Bohr, Dirac, Einstein and Schrödinger, and have only recently lost Rutherford and J. J. Thomson). If science be left free to expand, its expansion is inevitable, for science grows by accretion.

The unimportant composer or artist does nothing permanent to make his subject greater. The unimportant scientific research worker, on the contrary, places his brick firmly in position, and on it every subsequent worker in the same field —geniuses included—will build again. The knowledge that every step forward is an advance in a gigantic undertaking is an inspiration to the scientist, for he may legitimately feel that he is playing his part in the greatest adventure of the human mind. This knowledge is one of the supreme values of science to the investigator.

It is impossible to read the biographies of the greatest scientists without realizing the high value which they have attributed to science apart from its material benefits, but they seldom analyse their appreciation very explicitly. It is unquestionable that a pleasurable excitement in approaching the

unfamiliar is a part of the reason for their appreciation, an attitude of mind which is shared with the geographical explorer. A pleasure in finding order where previously disorder seemed to reign is another component of the scientific attitude. This has been stated quite unequivocally by the Danish genius of physics, Niels Bohr,[11] who writes that the deepest foundation of science is "the abiding impulse in every human being to seek order and harmony behind the manifold and the changing in the existing world." T. H. Huxley wrote in his *Method and Results* that the research worker is inspired by "the supreme delight of extending the realm of law and order ever farther towards the unattainable goals of the infinitely great and the infinitely small, between which our little race of life is run." [53] Some scientists, again, are animated by a component of that special awareness of the natural environment and feeling of community with nature and joy in natural beauty which also animate the poet and artist in their respective fields. This was clearly understood by the great German scientist, Alexander Humboldt, [50] who wrote of "that important stage of our communion with the external world, when the enjoyment arising from a knowledge of the laws, and the mutual connexion of phenomena, associates itself with the charm of a simple contemplation of nature."

Humboldt was a person of extraordinarily wide interests. As a young man he was a successful mining technologist, but his passion for travel drew him into wider and wider fields of study until it might be said of him that if ever there was such a person as a general scientist, it was he. Few men, if any, have ever made such substantial contributions to so many diverse branches of science; and it was not only science that engaged his attention, for he was also a diplomat of high rank and a political economist. The extraordinary breadth of outlook of this great man enabled him to see science as a whole, and he expressed very vividly what he saw. In a few words of the utmost simplicity he expressed a truth which our modern materialists cannot shake: "other interests," he wrote,

"besides the material wants of life, occupy the minds of men." He instanced the "desire of embellishing life by augmenting the mass of ideas, and by multiplying means for their generalization. . . . The higher enjoyments yielded by the study of nature depend upon the correctness and the depth of our views, and upon the extent of the subjects that may be comprehended in a single glance." These words are strikingly similar to those written by the philosopher, Alexander, not much less than a century later: "The greatest truths are perhaps those which being simple in themselves illuminate a large and complex body of knowledge." Such truths, when grasped, unquestionably bring pleasure to the mind; and it would be fantastic to deny the existence of this kind of pleasure or to assess it lower than crude or material kinds. "In considering the study of physical phenomena," said Humboldt, "we find its noblest and most important result to be a knowledge of the chain of connexion, by which all natural forces are linked together, and made mutually dependent upon each other; and it is the perception of these relations that exalts our views and ennobles our enjoyments."

The enjoyments appear subjectively to be of the same kind as those caused by the perception of artistic beauty, combined with wonder or even a pleasurable astonishment. Professor J. B. S. Haldane [42] has stressed the value of beauty in science in a particularly concrete way. "As a result of Faraday's work," he wrote, "you are able to listen to the wireless. But more than that, as a result of Faraday's work scientifically educated men and women have an altogether richer view of the world: for them, apparently empty space is full of the most intricate and beautiful patterns. So Faraday gave the world not only fresh wealth but fresh beauty." These simple words express a profound truth, which can be denied only as a tone-deaf man can deny the spiritual value of music. They are a distinguished investigator's flat contradiction of the materialist concept of science. Darwin expresses his feelings of beauty and wonder in the final words of *The Origin of Species*: "There

is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved." [22]

The finding of a kind of wonder or awe in the majesty and apparently infinite complexity of the universe has led some of the greatest scientists—among them Boyle, Hooke, Newton, and Trembley—to ascribe the value of science to its giving us an insight into the mind of God. The great Swiss-born American zoologist, Louis Agassiz, for instance, expressed this idea unequivocally: "If I mistake not, the great object of our museums should be to exhibit the whole animal kingdom as a manifestation of the Supreme Intellect." [47] This seems to be related to the subtler feeling of some of the greatest mathematicians that mathematical reality lies outside human beings, and that in their apparently creative work they are actually only observing and recording. [43]

The scientist is able to construct a sort of scale of scientific values and to decide that one thing or theory is relatively trivial and another relatively important, quite apart from any question of practical applications. There is, as Poincaré has well said, "une hiérarchie des faits." [81] Most scientists will agree that certain discoveries or propositions are more important because more widely significant than others, though around any particular level on the scale of values there may be disagreement. Thus, every scientist will agree that the discovery of atoms and of cells was important, and that the discovery of a new species of beetle, not markedly unusual in any way, is unimportant. So also with theories and "laws." A law, says Poincaré, "sera d'autant plus précieuse qu'elle sera plus générale." Professor G. H. Hardy [43] has shown how mathematicians value their ideas by generality and depth, and how they universally value general and deep theorems above mere isolated curiosities, such as the fact that 8712 and 9801

are the only four-figure numbers that are integral multiples of themselves written backwards ($8712 = 2178 \times 4$ and $9801 = 1089 \times 9$). A general theorem is one of wide significance, and a deep theorem one requiring a first understanding of a simpler theorem. Both these ideas are continually being used, consciously or unconsciously, whenever one scientist says that another has done a "good" bit of work.

The existence of amateur scientists is a proof that science is appreciated as an end. The amateur plays a smaller part in scientific research than he did in the eighteenth and nineteenth centuries, but excellent work is still done by amateurs in geology and biology (see pp. 90–91). Apart from those who are sufficiently interested to rank as amateur scientists, there is a mass of people who possess the same sort of feelings as the great investigator but in lesser degree. For instance, a markedly strange animal of any kind arouses great public interest in both savage and civilized communities, and no sharp dividing line can be drawn between this sort of interest and that which inspires the zoologist, though the latter's interest is of course greater and more lasting. One has only to think of the interest taken by the most diverse people in the microscopical discoveries of van Leeuwenhoek to realize how widespread is an interest in unfamiliar natural objects. When it was discovered by Abraham Trembley almost exactly two hundred years ago that an organism exists (we now call it *Hydra*) which feeds like an animal but buds like a plant, and reorganizes itself into two or more individuals if cut into bits with scissors, the interest aroused was such that polyps became, in the words of an anonymous eighteenth-century writer, "à la mode." [3] Interest in the unfamiliar is abundantly illustrated by the history of science. Even in modern times, when people tend to be less enthusiastic than they were two or three centuries ago, the discovery of a living fish belonging to a group thought to have been extinct for some sixty million years caused great excitement, and a popular weekly journal devoted a large double page entirely to the event.

Just as the unfamiliar attracts the interest of both layman and scientist, so also does the orderly. In a low form one sees the appreciation of the orderly exhibited in a collection of butterflies systematically arranged by a collector who understands little of the life-processes of what he collects. No sharp line of separation can be drawn between the simple arrangement of natural objects in an orderly fashion and the systematic presentations of natural knowledge by great scientists. I found this out many years ago when demonstrating to a class of students preparing for the final Honours examination in zoology at Oxford. We were studying the anatomy of certain marine worms, and I noticed that one of the women-students had a book beside her, open at a coloured plate showing the external characters of some of the animals that we were studying. The book was unfamiliar to me and I stooped down to look at it. The name gave me a surprise that I have not forgotten. I learnt a useful lesson in modesty that day, which I should be happy to share with any scientist who thinks himself a different kind of being from the layman. The student, preparing for the highest examination in zoology at a great university, was using *The Seashore shown to the Children*.

There is a widespread belief in the "worth-whileness" of finding out. The community as a whole appears to approve of the setting apart of a limited number of talented people for the express purpose of discovery, without requiring that all research should be directed towards material ends. The public expects as almost a matter of course that some one or other should concern himself with all branches of natural knowledge. This was forcibly brought home to me some years ago when I was one of the three or four people in the world who were making systematic studies of the causes of breeding seasons. When I remarked to non-scientific friends that the environmental causes which regulate the breeding seasons of animals were not known—that no one knew what makes the blackbird breed in early spring—I was met by frank

incredulity. "Oh, *some one* knows," I was assured; "the experts *must* know." It seemed intolerable that a community which maintains people expressly for the purpose of getting all sorts of knowledge should not be able to obtain information on such a very straightforward and familiar subject.

There is one particular kind of knowledge which both the scientist and the layman place high up on the scale of values. This is the knowledge that throws light on man's place in the universe. The discoveries of Copernicus and Darwin caused a ferment of excitement which shook and changed the outlook of the whole civilized world, quite apart from any application to material human welfare. Again, one's whole outlook on the universe is changed and broadened by the knowledge that great groups of animals, some of them of gigantic bulk, have arisen in the distant past, evolved, persisted for millions of years, and then become totally extinct millions of years before man, or even his ape-like ancestors, appeared on earth.

5. *The Appreciation of Appreciation*

One of the values of science to the scientist is of a kind that is so generally understood in all fields of human activity that it is only mentioned here for the sake of completeness. The successful investigator appreciates the appreciation of others, provided that the others are qualified to judge. The extent to which scientists are affected by the desire for the approval of others varies widely. One of the greatest, Henry Cavendish, was so little affected by it that he did not bother to publish some of his most marvellous discoveries. Most scientists, however, naturally like their colleagues to think well of them, and they value science partly because it is an activity in which they can earn the approval of others.

6. *Has Truth Intrinsic Excellence?*

So far we have been considering value as equivalent to the existence of conscious appreciation. Another aspect of the value of science, attractive to the intuitions of many people, may be illustrated by an imaginary event.

Let us suppose that a group of psychologists, having armed themselves with a marvellous new invention which enables them to assess happiness objectively, accompanies a scientific expedition which sets out to explore two islands. When they analyse their data, they find that the average happiness or general contentment of the people on the two islands is exactly the same. Meanwhile the anthropologists of the expedition have been studying the natives' outlook on the universe. On the one island thunder is ascribed to the anger of the tribal ancestors, boiling springs are regarded as giants' cooking vessels, the birth of twins is regarded as indicating that the agricultural crops will be prolific, etc. On the other island these and other natural phenomena are interpreted in accordance with the scientific ideas with which we are familiar. In both islands the phenomena are regarded with interest, which is equal in the two cases. Which is the better civilization (apart from future prospects)?

There may be sceptics who will deny that a balance can be held between the two islands. Others may consider that if one island's civilization is better than the other, that is solely because some external observer appreciates the one civilization more highly, for in the absence of an external observer no difference exists. Most people, however, are likely to say that the civilization in which there is true knowledge is the better. Truth, in fact, has intrinsic excellence, apart from its effects. This belief—for it seems impossible to prove or disprove in any formal way the statement that truth has or is a value—has been a mainspring of scientific research, particularly plainly exhibited in the lives of such scientific geniuses as Charles

Darwin and T. H. Huxley, but animating also many much lesser men and women.

Diametrically opposite to these ideas stand those of the rulers of totalitarian states. Some general remarks on the subject are attributed to Hitler: "There is no such thing as truth. Science is a social phenomenon, and like every other social phenomenon is limited by the benefit or injury it confers on the community." [87] Himmler has applied these principles to a particular case, when attacking German scholars who refused to acknowledge the genuineness of a forged document on German archæology. It surprised him that anyone should make a fuss as to whether it were true. "The one and only thing that matters to us," he is reported to have said, "and the thing these people are paid for by the state, is to have ideas of history that strengthen our people in their necessary national pride." [87] As the Nazi professor of philosophy at Heidelberg announced, "We do not know of or recognize truth for truth's sake." [108] For Hitler and Himmler and the Nazi professor it seems nonsense to worry whether a given statement is true or not: the only thing that matters is how that statement affects the community. It is probable that few first-rate scientists would assent to what they regarded as an untruth, even if they could be persuaded that such assent would be materially beneficial to the community. It is apparent that the orderly structure and dependability of science would become transformed into chaos if Hitler's and Himmler's ideas were accepted by scientists as a whole; and scientists have always been accustomed to place a very high value upon truth, generally without considering the philosophical background of the position that they adopt.

7. *Propaganda fostering a Feeling of Disillusionment in Science*

Not only in Germany, but in the U.S.S.R. and Britain as well, movements have arisen which are in opposition to the opinion that science has a value as an end in itself. Although

some of the writings of these schools contain so many contradictions that precise refutation is rendered impossible, yet there is no doubt that the intention is either to deny the value of science altogether apart from its purely material services, or else greatly to minimize it. Professor J. D. Bernal, for instance, sneered at science outside the Soviet Union as an "elegant pastime."[9] Elsewhere he writes of science (apart from its practical applications) as a "game."[8] There is no economic system, he says, which is willing to pay scientists "just to amuse themselves." Science, he says, "has all the qualities which make millions of people addicts of the crossword puzzle or the detective story, the only difference being that the problem has been set by nature or chance and not by man, that the answers cannot be got with certainty, and when they are found often raise far more questions than the original problem."[8] These, the reader should note, are said to be the *only* differences. Professor Bernal has attacked the high ideal of science as presented in T. H. Huxley's *Method and Results* and said it was a form of snobbery, "a sign of the scientist aping the don and the gentleman. An applied scientist must needs appear somewhat of a tradesman; he risked losing his amateur status. By insisting on science for its own sake the pure scientist repudiated the sordid material foundation on which his work was based."[8] All this is propaganda fostering a feeling of disillusionment in science.

A very interesting sidelight on the fostering of disillusionment in science is provided by Mr A. L. Rowse, Fellow of All Souls College, Oxford, in his recent book, *A Cornish Childhood*.[90] On pp. 174–175 he tells us that from the first he shared "the aversion which nearly all the most intelligent men I have met since have had for science." "I am not merely uninterested," he insists, "I am positively anti-scientist." He thinks people should learn science, if at all, "after they have been educated. . . . And of course I regard the tremendous cult made of science in modern society as very exaggerated: scientists have been very skilful in putting themselves across,

and they have a vociferous and docile claque to support them in their claims." Modern society rests upon scientific foundations "in the sense that a modern town rests upon a proper sewage and drainage system." Having produced this propaganda of disillusionment in science, Mr Rowse goes straight on to say that he is "in entire sympathy" with a certain contemporary movement in science. The members of this movement, he says, are mostly friends of his. He mentions a string of six of them—and they are six of the seven leading figures in the movement for the central planning of science.

If the movement responsible for the propaganda of disillusionment in science could gain power, it would gravely damage science. Already its power is considerable, not only in the U.S.S.R. and Germany, but also in Britain. Influenced by the thoughtless desire to be considered modern and fashionable, a desire that is unaffected by the ups and downs of civilization, many young scientists are beginning to tread a course which, if it succeeds, will lead to the eclipse of their subject. The situation is the more threatening because nowadays, as a result of the expansion of science, there is a far higher proportion of scientists who are not enthusiasts than in previous centuries. It will be suggested in Chapter V that the first social responsibility of scientists is to oppose the threat.

Chapter III

FREEDOM OF INQUIRY

"The real scientist . . . is ready to bear privation and, if need be, starvation rather than let anyone dictate to him which direction his work must take."—SZENT-GYÖRGYI.

1. *The Nature of Free Inquiry*

FREEDOM of inquiry means the freedom of the research worker to decide what he will investigate. It has been said contemptuously that such freedom would enable a man to spend his life, at the expense of the community, in proving that the earth is flat. This idea must be contradicted. The research worker who does not do good research betrays his trust, either through lack of gift or as a result of laziness. The value of his research can be assessed only by his fellow-scientists. Their judgment may be wrong, but no better criterion of excellence exists. No scientist should be paid to continue indefinitely with trivial or negligible research. He must not, of course, be hurried to produce results—that would be fatal; but if, over a period of four or five years, he is consistently unfruitful, facilities should be given him to engage in some scientific activity other than research. Some one else will then be free to take his place.

Let it be clear that freedom of inquiry does not and cannot mean perfect freedom. A scientist who wants to work at the tree-top fauna of the Brazilian forest can generally be free to do so only if he can persuade other people that his study is likely to be fruitful: then and then only will funds be forthcoming. Similarly, scarcely anyone is free to have a cyclotron or an ultra-centrifuge at his disposal unless he can make other people believe that his use of such an expensive instrument would result in important advances in science. An enormous amount of scientific work can be done, however, with little expenditure, and in so far as his imagination directs him

towards relatively inexpensive studies, the established research worker in a British university is generally remarkably free.

Aldous Huxley has made one of his characters say that the real charm of scientific research is its easiness. The exact contrary is true. A life of free research is very strenuous, because the investigator must continually be making decisions on matters in which he has only his intuition to guide him. It is generally recognized that it is hard and anxious work to make decisions with inadequate information, and all the more so if the result of the decisions determines the success or failure of the person who makes them. The investigator must continually be deciding what he will do next in the laboratory and what he will read in the library, and how much time he will spend in each. Continually new possibilities of investigation suggest themselves to him as a result of what he does or reads. A wrong decision may waste months, a right one may bring great success. The life is too strenuous for most people, and the timid scientist hankers after the safety of directed team-work routine. The genuine research worker is an altogether different kind of person. He gets the ideas on which scientific research depends at the most extraordinary and unpredictable times, seldom when he is expecting them. If the idea is a good one, a complete change of research plans may be necessary. It may take months to discover whether it is a good idea. He quietly weighs the risks. If he considers the chance good enough, he throws over what he is doing and enters with enthusiasm into the new investigation. He will gain or lose according to the correctness or falsity of his judgment. Only a man of courage, independence, and lively imagination will take big risks for the possibility of big discoveries. "I am like a gambler," wrote Charles Darwin, "and love a wild experiment." [23]

The great biochemist, Szent-Györgyi, has written these words: "What I want to stress is that the pre-condition of scientific discovery is a society which does not demand 'usefulness' from the scientist, but grants him the liberty which

he needs for concentration and for the conscientious detailed work without which creation is impossible. . . . The real scientist . . . is ready to bear privation and, if need be, starvation rather than let anyone dictate to him which direction his work must take." [98] These are the opinions of the man who was the first to isolate a chemically pure vitamin. He is a Nobel Prizewinner for Medicine.

Faraday administered a most effective and at the same time courteous rebuke to a would-be planner who wanted to make him continue some technological researches on glass. He said that as he had been obliged "to devote the whole of my spare time to the experiments [on glass] already described, and consequently to resign the pursuit of such philosophical inquiries as suggested themselves to my own mind, I would wish, under present circumstances, to lay the glass aside for a while that I may enjoy the pleasure of working out my own thoughts on other subjects." [30] Instead of improving glass, Faraday went on to the researches in science that made him one of the greatest investigators the world has ever known and revolutionized industry as well.

2. "*Overlapping*" *in Research*

When there is freedom of inquiry, two or more research workers often do the same sort of work independently at the same time. People argue that if the whole of scientific research could be comprehended under a central organizing authority, this overlapping could be avoided. The belief that it is obviously desirable to avoid overlapping must, however, be contested. It is necessary to enter in some little detail into this seemingly simple matter.

Every research worker needs a large store of *judgment*. A constant stream of scientific papers is flowing forth from all parts of the civilized world, and the scientist's decision as to what he shall investigate depends on what he believes in those papers. It would be ingenuous to imagine that each paper

contains nothing but the truth. Papers contain errors of fact, slips and misinterpretations, and the scientists who write them often deceive themselves by adherence to fashionable hypotheses. The scientist takes nothing as true on anyone's authority, for he knows that every investigator may make mistakes. Nevertheless, he cannot check every statement in every paper he reads. If he tried to do so, he would spend his life on nothing else—and would be able to read very few papers. He has got to be able to form a judgment of what is true.

His judgment is helped when one scientist repeats the work of another and publishes his results. There is one occurrence, however, which helps the scientist to form a valid judgment better than anything else. This is the simultaneous or nearly simultaneous publication of the same result by two entirely independent workers. Central planners are inclined to consider that one of the two independent workers has been wasting his time. The actual research worker knows that this is not so. It is the very fact that the two workers are independent that inclines others to accept their findings. Scarcely a working scientist will deny that two independent papers containing the same result are very much more convincing than a single paper by two collaborators. Independence has another advantage. If the two had been working together, their minds would have tended to run along the same track. Since they did not, each paper has a different outlook, and the reading of the two papers is far more stimulating and suggestive. An excellent example is provided by the almost simultaneous publication of the two papers that founded our modern knowledge of valency (see p. 49).

Some degree of isolation from other scientists is conducive to originality. There is an optimum amount of contact, which should not be exceeded. Anyone who doubts this should reflect how damaging to research it would be, if the teaching of science at all universities throughout the world were exactly the same. Each scientist can hold only a small

fraction of the available information in his head, and it is desirable that different scientists should think different thoughts. It is obvious that one can spend too much of one's time in the library, and single-track-mindedness is even more contagious by personal contact than infectious through print.

3. *Chance in Research*

The free investigator makes his own plans for research, but does not keep to them inflexibly. He has the courage and determination to throw away the toil of months if he gets an idea which he judges likely to lead to greater results. He is always alert and ready to switch his energies in a new direction when the unexpected appears. Chance may offer him a great new opportunity. The element of chance has always been important in scientific research, and only by free inquiry can the utmost use be made of it.

One of those who believe in the central planning of science [21] has said that freedom was useful to the science of the eighteenth century, but is not suited to the twentieth. I therefore select an investigation that is still in active progress to-day, as an example of the way in which free science still produces great results in modern times. The investigation is of high intrinsic and practical interest. The story of the discovery of the new therapeutic agent, penicillin, illustrates in a remarkable way how unpredictable the course of discovery is, and how free science produces results which could not be centrally planned.

In 1929 Dr A. Fleming,[32] working at St Mary's Hospital, London, left a number of culture-plates of staphylococci exposed from time to time to the air. The plates became accidentally contaminated by various micro-organisms. On one plate there grew a mould, *Penicillium notatum*. Dr Fleming noticed that round that mould the staphylococcus colonies died. The mould produces an anti-bacterial substance. This was not in itself a novelty, for it had been known for a long time that one micro-organism sometimes inhibits the

growth and multiplication of another. Dr Fleming filtered a broth culture of *Penicillium*, and called the filtrate penicillin. He made practical use of this substance in separating *Hæmophilus influenzæ*, which is resistant to it, from other bacteria. He suggested the use of penicillin in the local treatment of infected wounds. Unsuccessful attempts were made to isolate the bacteriostatic substance, and the subject lapsed from immediate interest.

In 1939 it occurred to Professor H. W. Florey and Dr E. Chain, of the School of Pathology, Oxford, that it would be profitable to conduct an investigation of the chemical and biological properties of the anti-bacterial substances produced by bacteria and moulds. They decided by great good fortune to start work with Fleming's mould. The results are well known.[16] Penicillin is a bacteriostatic agent with properties that can only be described as astonishing. It prevents the multiplication of certain bacteria at a dilution of one part in fifty million, yet it is harmless when injected into the body at high concentration. As Dr Chain has himself said to me, it would have been absolutely impossible to plan a research to find such a substance, because the existence of such a substance was not envisaged by anybody.

It is necessary to stress the great element of chance in this investigation. *Penicillium* came by chance to one of Dr Fleming's cultures, when he was not studying the influence of one micro-organism on another. That is only a small fraction of the element of chance in this case. Hundreds of species of *Penicillium* have now been examined, and penicillin has been found only in *Penicillium notatum*, the species which alighted on Dr Fleming's culture. That again is by no means all. There are sixty strains of *Penicillium notatum*. and only one of these—Dr Fleming's—produces penicillin. Again, penicillin may be the only really valuable antagonistic substance produced by moulds or bacteria, and Dr Chain and Professor Florey might have chosen one of about twenty others for their study.

In stressing the action of chance, which I believe to play—now as in the past—a very large part in discovery, I wish to make it clear that chance does not detract from the credit due to Dr Fleming, Professor Florey, and Dr Chain for their remarkable discoveries. As Pasteur himself said, "Chance only favours prepared minds." [106] Lagrange said almost exactly the same thing: "Accidents only happen to those who deserve them." [104] Réaumur had already said it even more precisely when Lagrange was yet only six years old. He was referring to the wonderful discovery of regeneration made by Trembley when the latter had chanced to find *Hydra* in some water collected in a ditch. "Chance alone," wrote Réaumur, "has given the opportunity for a discovery to be made which reason scarcely permits one to believe [even] after one has seen it; but it was one of those chances that only offer themselves to those who are worthy to have them, or rather, to those who know how to procure them." [88] These are thoughtful words, and as applicable to-day as they were two hundred and two years ago.

When once Professor Florey and Dr Chain realized that they had made a great discovery, it was a straightforward matter to plan how it should be followed up. It was necessary to find a way of culturing the mould on a large scale; to devise standards for assaying it; to get it as pure as possible and attempt analysis of the active principle; to carry out fuller tests of harmlessness and bacteriostatic activity; and to try its administration to man. [1] This is exactly the sort of situation in which organized team-work is valuable: the primary discovery has been made, and the follow-up can be planned. A team of workers co-operating with the original discoverers promises to give the world one of its most important therapeutic agents (Abraham, Chain *et al*, 1941). At present the chief requirement is a knowledge of how to increase the yield of penicillin, or how to synthesize its active principle. Meanwhile, the results of its use are already very encouraging, indeed astonishing, in the treatment of a wide variety of illnesses.

4. *The Contribution of Solitary Workers to Twentieth-century Science*

Professor J. D. Bernal has said that "practically the whole of the great advances of science in the twentieth century were achieved not by scientists working as individuals, but in organized groups." [9] Mr Swann has said almost exactly the same thing: "Only a small proportion of the scientific discoveries made in this or any other country are due to individuals working on their own." [97] Statements of this kind tend to be repeated and gain credence. It is easy to refute them. In the first place, when two or three scientists work and publish together (in this century as in the last), they cannot, in the majority of cases, be said to form an organized group. No one has coerced them into working together. They find it convenient, for a special purpose, to collaborate. That is a very different thing from organized team-work, such as that in force at the Physico-Technical Institute at Kharkov, in the U.S.S.R., where the investigators are organized in brigades, and no one is allowed to start working on a new problem without permission. [18] That is an organized group, and one can say confidently that such organized groups have made only a relatively small contribution to discovery.

The second part of the answer to Professor Bernal's statement shows him even more clearly to be wrong. Here, there is no question of the interpretation of terms. He says unequivocally that single investigators have contributed almost nothing to the great advances of science in the twentieth century. Let us consider that.

What about Einstein? Is it really possible to forget about him? "I am a horse for single harness," wrote Einstein, "not cut out for tandem or team-work." [54] This was the man who suggested jobs as lighthouse-keepers for refugee scientists, so that they might have the isolation necessary for scientific work.

Einstein alone demolishes Professor Bernal's statement, but

no one must be allowed to think that Professor Bernal forgot about Einstein and was in other respects well informed. In many branches of science the fundamental discoveries have been made by scientists working as individuals, in this century as in others. The following are a few examples chosen at random from various sciences.

Probably the most fundamental problem in chemistry is the nature of the forces that hold atoms together, and in particular the nature of the bonds of valency. Our understanding of this problem dates from 1916, when two papers were published independently, the one in March in Germany, the other in April in the U.S.A. Although some preliminary ideas had already been published by Sir J. J. Thomson and Sir William Ramsay, yet Walther Kossel's "Über Molekülbildung als Frage des Atombaus" [62] and Gilbert N. Lewis's "The Atom and the Molecule" [66a] are the foundation of modern knowledge of valency. Both were workers who published under their own names alone. This does not mean that they lived like Trappist monks, and Lewis mentions the discussion of certain aspects of his subject with his colleagues; but our understanding of the nature of valency is due to the genius of these two independent workers. Kossel concentrated on electrovalent and Lewis chiefly on covalent linkages (without at the time appreciating the difference). Three years later, when Irving Langmuir published his well-known paper on "The Arrangement of Electrons in Atoms and Molecules," [66] he began, necessarily, by full references to the work of Kossel and of Lewis. Every chemist will allow that the fundamental work leading to the modern theory of valency was done by scientists working and publishing separately.

The same applies to the fundamental work in cytogenetics. The close parallel between the results of Mendelian breeding experiments and the behaviour of the chromosomes was first pointed out by a scientist, W. S. Sutton,[96] working as an individual. Sutton's paper constituted the actual origin of

cytogenetics. The next most important step was the production of evidence that the sex chromosomes are concerned with sex determination. This was done by C. E. McClung,[71] who was also working as an individual though he directed his students to similar studies. McClung's fertile work was followed by that of the great cytologist, E. B. Wilson, who first established the true facts about the relationship between the sex chromosomes and sex determination in a series of papers written by himself alone. [110]

We may turn to any part of science and we are likely to find the same thing: the fundamental discoveries are commonly made by single workers. The elusive Golgi bodies, so long undetected but now known to be a component of almost every animal cell, are nearly always made visible by one of two methods: either by their capacity to reduce osmium tetroxide very slowly, or else by the so-called photographic method, in which silver nitrate and a photographic developer are used. The osmium tetroxide method was discovered by a solitary worker (F. Kopsch), [61] and so was the photographic (by S. Ramon y Cajal). [86]

In the wide and intensely interesting subject of experimental embryology, to take another example, almost all the fundamental twentieth-century discoveries have been made by single workers. This is the subject which concerns itself with the experimental analysis of the causes that make an apparently simple egg develop into an excessively complicated adult organism. The organ-forming potentialities of the various parts of the egg were described in the well-known papers of the American, E. C. Conklin.* W. Vogt, working alone, introduced the method of staining small parts of the living embryo and thus following those parts during development. His maps of the presumptive regions of the embryos of Amphibia, made in this way, are famous. The descriptive method introduced by Vogt has thrown a flood of light on

* References to the work of the experimental embryologists mentioned may be found, *e.g.*, in Huxley and de Beer.[52]

experimental studies in embryology. The concept of axial gradients or gradient-fields was developed independently by T. Boveri in Germany and C. M. Child in America—both single workers. The momentous discovery of the "organizer" is due to the solitary work of H. Spemann, who, although he collaborated with Mangold in a well-known paper, yet had previously discovered the essential principle in independent research. Finally, that classical work *On Growth and Form* is the achievement of the single mind of D'Arcy Thompson,[101] though he acknowledged the informal help of his friends. I believe that scarcely any biologist will deny that the separate and solitary work of Conklin, Vogt, Boveri, Child, Spemann, and D'Arcy Thompson has been, in this twentieth century, of altogether outstanding importance.

The study of vitamins tells the same story. The concept of a deficiency disease is due to the Dutchman, G. Grijns,[38] who suggested at the beginning of this century that a diet containing sufficient proteins, carbohydrates, fats, salts, and water might fail to sustain life.* This was directly contrary to the scientific opinion of the day. Grijns's collaborator, E. Eijkman, was influenced by the prevailing opinion, and it was not until Eijkman had returned from the East Indies to Holland that Grijns was able to arrive at his astonishing conclusion. Grijns was working at what we now call vitamin B1 or thiamin, and this substance was first obtained in (impure) crystalline form by another solitary worker, C. Funk.

Hormones tell the same story again. Thyroxine, for instance, was first isolated by E. C. Kendall,† and the parathyroid hormone by J. B. Collip. J. Takamine gave the first satisfactory method of extracting adrenaline. A. Butenandt was a pioneer in the isolation of sex hormones.

The story is endless. Almost every scientist can continue it. Fleming's discovery of penicillin is an example. Professor

* Rigorous proof of this fact was given later by F. G. Hopkins.

† For references to work on the isolation of hormones, see Harrow and Sherwin.[44]

Bernal's statement that "practically the whole of the great advances of science in the twentieth century was achieved not by scientists working as individuals, but in organized groups" is contrary to the demonstrable facts. The solitary worker has made an enormous contribution to twentieth-century science.

The solitary worker owes much to others—to all those who gave him encouragement as a child or at any time, to his teachers in school and university, to the authors of papers and books on his subject, to colleagues who chat with him, to architects and engineers who provide him with a laboratory, to editors, publishers, and printers who make his discoveries known, to laboratory assistants who give him practical help. The community helps him: he makes return primarily by the discovery of demonstrable facts. He finds that he makes the best return when he directs his own research and carries it out as he thinks fit. He desires to dominate no one and to dictate to no one how research shall be carried out, but he considers that in the best interests of science he, and others who feel as he does, should be free to work alone.

5. *The Place of Teams in Research*

In strong contrast to directed team-work stands the co-operation of two or three scientific friends. Such co-operation has produced a great deal of excellent scientific investigation. It was the friendly collaboration between Schleiden, the ex-lawyer and botanist, and Theodor Schwann, the anatomist, that brought the cell theory into existence.[33] The two men, both in their thirties, were dining in Berlin in October 1838. Schleiden described to Schwann the nucleus of plant cells. Schwann at once recollected that he had seen a similar structure in cells of the Vertebrate spinal cord. The two men went forthwith to the University Anatomical Institute, where Schwann carried out his researches. Schwann showed Schleiden the cells of the spinal cord, and Schleiden at

once recognized the nuclei as the same structures as those with which he was familiar in plants. Although a good deal was already known about cells from the pioneer work of Dutrochet, Turpin, Brown, von Mohl, Purkinje, and Müller,[17, 93] yet this occasion may justly be regarded as that to which we owe the first general formulation of the cell theory. The two men were not coerced to work together: in fact, they worked and published separately. Although they made big mistakes, yet their work served to focus attention on the cell and to show how it forms the basis of the structure of both plants and animals.

The sort of informal intercourse that Schleiden held with Schwann, as well as closer collaboration resulting in the publication of joint papers, has long been of great importance in discovery. One of the most valuable kinds of scientific collaboration is indeed entirely informal. Every investigator could illustrate this from his private experience. For instance, I have never had a formal conference with either of the two men who occupy the research-rooms next to mine, but we naturally meet accidentally in the passage and exchange a few remarks, or drop in on one another to ask a question; and it would be hard to exaggerate the benefit that my research has gained from friendly help given in these chance encounters.

People who like to control everything under an orderly plan cannot believe that independent research and informal collaboration are more *efficient* than directed teams. It is urgent, for the sake of the welfare of science, that people who worship mere tidiness should occupy themselves in some suitable and congenial occupation and not strive to impose impossible conditions of work on the original scientific investigator, whose mind they can never hope to understand. The would-be central planner of science is a menace to progress. The Archbishop of Canterbury has said, "There is a real danger of planning in this country being carried out for the wealth or the power of the planners."[15] We cannot tell whether the planners want wealth or power or only tidiness,

and their motives are private and irrelevant; but the Archbishop has done well to point out the danger, which threatens science as much as any other human activity.

The proper function of a research team is to work out the consequences after an independent worker or two or three scientific friends have opened a new line of investigation. There will be plenty of people who want to follow the new line. Indeed, one notices a strong tendency for scientists to ask, "What is being done?" They might as well ask frankly, "What is the fashion?" The original investigator on the contrary asks himself, "What is *not* being done?" The people who want to *follow* a new line often do excellently in teams and they can be fitted satisfactorily into planned research. They have neither the wish nor the ability to think originally, though they are often talented, well equipped technically, and possessed of a great love of knowledge. If science is to flourish, however, encouragement must be given to people of independent spirit who want no master. The desire to know is widespread among men: the desire to know specifically that which is not known is on the contrary very rare.

Although teams have their place in scientific research, yet they also have grave disadvantages. As the director of a research team once said to me, "The trouble with a team is that directly a man has joined it, he doesn't bother to have ideas any more." The statement was an exaggeration, but it contains an important element of truth. If the investigator works in a team, it is difficult for him to allow ideas to grow in his mind. He knows that his colleagues will frown upon his wish to give up what he is doing, for that will disturb their work. He knows also that instead of throwing himself into the congenial task of entering immediately on the new work, he will have to devote most of his energy to the very uncongenial task of trying to persuade the director of the team to allow him to upset all the carefully prepared plans. His position is exactly what that of a composer would be if he

had to get other people's agreement before he could work out in detail the themes that occurred to him in moments of inspiration.

The free research worker is never on holiday. He must always, day and night, be ready for the arrival of an idea. He can only achieve that readiness by so arranging his life that ideas may come. He cannot order them to come, but he can and must provide an environment in which their coming is a possibility. For this some solitude and mental quiet are necessary. He lives for his research not only when he is in the laboratory or library, but right round the clock. My friend Dr V. Korenchevsky was present when Pavlov, the famous Russian physiologist, was asked for a recipe for success in scientific research. His advice was simple. Get up in the morning with your problem before you. Breakfast with it. Go to the laboratory with it. Eat your lunch with it. Take it home with you in the evening. Eat your dinner with it. Keep it before you after dinner. Go to bed with it in your mind. Dream about it.

It is impossible to live for ideas when one knows that their coming will simply mean a public contest as to whether they shall be tried out. Until an original idea has been tried, its very originality ensures that it is something *unlikely* in the existing state of knowledge. Ideas are rightly the personal property of their conceivers until they have been tried. When they have been tested and proved, the scientist has a duty to publish them, for there should be no private property in demonstrable knowledge; but the original idea is something personal and private until its truth or falsity has been demonstrated.

The picture of the great scientist sitting in his study throwing off ideas for his vassals to work out in the laboratory is fantastic, for two reasons. First, no matter how great a scientist may be, worth-while ideas are definitely rare, and are most likely to come if the scientist spends a good part of his time in manual work in the laboratory. Secondly, every vassal who

carries out the great man's ideas is by that very fact precluded from carrying out his own, and so he will seldom "bother" to have any.

The team is an excellent institution for carrying out an obvious bit of work, provided that it does not take an original mind away from free research; but it is not an organization for producing ideas. It is a group of specialists, each devoting his special knowledge to one side of a problem; and there is always grave danger that no one is seeing the problem as a whole. The director himself is likely to be too much occupied with administrative work, too eager to seize every opportunity to rake in some more funds for the research, too energetic in making all the right contacts, too liable to prefer the committee-room to the laboratory to have the mental repose necessary for true originality. If a man is good enough in his subject to be the leader of a team, he is likely to be wasting his talent; for he may be good enough to have the privilege of being allowed to work alone.

6. *Cancer and Freedom of Inquiry*

The planning enthusiast would deny freedom to the research worker because he thinks central direction more efficient. In my last book, *The Scientific Life*, [6] I pointed out (on p. 75) that Röntgen and the Curies, who helped sufferers from cancer more than anyone else ever has before or since, did not engage in research on cancer. On the contrary, they investigated X-rays and radium, without thought of malignant tumours. They were simply very talented people who were allowed to carry out their own experiments for the purpose of increasing knowledge. "It may be anticipated," I continued, "that when another great discovery comes to bring help to sufferers from this disease it is likely to come from an equally unexpected quarter." It is an amiable foible of the human race to like being able to say, "I told you so." Not being an exception to the rule—who, indeed, except Mr Winston Churchill, can

claim to be that?—I cannot forgo the pleasure. What I said has come true.

The newspapers have splashed the information about the control of prostatic cancer. The facts are certainly impressive. American statistics show that about five per cent. of men over fifty years of age die of cancer of the prostate gland. This terrible disease is extremely painful, emaciates the patient and may even paralyse him; it leaves him without appetite or the desire to live.[25] A method of controlling this disease has now been found, which is often successful. It involves no operation. "To see these symptoms removed," says the Editor of the *Lancet*, "appetite for food and life restored, and the patient once more a useful citizen is a dramatic experience."[25] Dr Charles Huggins, who has had so much to do with the discovery of the new method of treatment, has written as follows: "It is striking to see patients emaciated from malignant disease develop a voracious appetite . . . pain often disappears. . . . The increased food intake and decrease of pain promote a sense of well-being and more tangibly a gain in weight and increased blood formation so that the anæmia accompanying the tumour frequently disappears."[49] What is the origin of this marvellous discovery? The newspapers, of course, never tell us that: they give all the credit to those who fasten the last link in the chain. The discovery has its roots in the eighteenth century and owes its existence to two separate departments of knowledge, both apparently unrelated to cancer and also to each other.

The prostate gland is a male accessory organ of reproduction, situated near the base of the urinary bladder. Its function is to add a secretion to the semen,* favourable to the activity of the spermatozoa. To trace the history of the control of

* For the sake of any boy or girl reader who may be unfamiliar with the word *semen*, I mention that this is the fluid passed from male to female at sexual union. It contains many microscopical male germ cells or spermatozoa, one of which fuses with the female germ cell or egg, which is also microscopical in the case of mammals (including human beings). The product of fusion grows and becomes the embryo.

cancer of this organ it is necessary to go right back to that grand old eighteenth-century physiologist and surgeon, John Hunter; for it was he who first noted that the prostate of a castrated animal (a bullock, to be precise) is small and flabby and contains little secretion. It was not until 1847 that Dr W. Gruber,[40] of St Petersburg, made the same discovery for man. Subsequent workers noted the same fact from time to time, and at last, in 1889, a serious study of the relationship between the testes and the prostate was published by Joseph Griffiths,[37] of Cambridge University, who had investigated the seasonal changes in size of the prostate gland in the mole and hedgehog and noticed the effect that castration has on that organ in the dog and cat. As we should say now, the testes produce a hormone or chemical messenger which circulates in the blood and stimulates the prostate to grow and secrete. When the testes are removed, the prostate declines. In 1926 Steinach and Kun [94] showed that injection of the female hormone into male animals also causes a rapid decline of the prostate gland.

That is one of the roots of our modern knowledge. The other is in biochemical studies having, at first, no connexion whatever with the prostate gland or with cancer. It was in 1912 that Grosser and Husler, [39] working at a children's clinic in Frankfurt, first discovered *phosphatase*. They discovered it in the lining membrane of the intestine. Phosphatase is a ferment capable of releasing phosphoric acid from certain of its compounds. The next discovery of importance was made almost simultaneously but independently in 1934 by D. R. Davis [24] at the Welsh National School of Medicine at Cardiff and by Baaman and Riedell [5] at the Technical High School at Stuttgart. These workers discovered that there are in fact two different phosphatases, the one active in acid and the other in alkaline media. Next year Kutcher and Wolbergs, [63] of the Physiological Institute of the University of Heidelberg, made the discovery that was to link together two lines of research. They found that human prostatic secretion is very rich in "acid" phosphatase, that is, the phosphatase that is active in

acid media. (The significance of the presence of a relatively high concentration of acid phosphatase in the secretion of the prostate is irrelevant to our discussion.)

Our modern knowledge of how to control cancer of the prostate is due to the researches of these men—of Hunter, Gruber, Griffiths, Steinach, and Kun on the prostate; of Grosser, Husler, Davis, Baaman, and Riedell on phosphatase; and of Kutcher and Wolbergs on phosphatase in the prostate. *Not one of these men was studying cancer*, yet without them the discovery of the new treatment would not have been made.

Now at last we come to cancer itself. A. B. and E. B. Gutman,[41] of New York, discovered in 1938 that the *blood* of patients with cancer of the prostate often contains more than the normal amount of acid phosphatase. Malignant prostate cells retain the capacity to produce phosphatase shown by the normal cells of that organ, and pour it into the circulation. High amounts of acid phosphatase constitute a symptom of the disease and a means of diagnosis.

It was this knowledge that put Dr Charles Huggins,[49] of Chicago University, on the path that led to success. It was he and his associates who connected the knowledge of the hormone control of the prostate with the knowledge of the production of phosphatase by that organ. It occurred to them to try removing the testes of some patients and supplying the female hormone to others, to check the secretory activity of the malignant cells and thus to reduce the amount of phosphatase in the blood. Not only did they succeed in controlling the symptom: they controlled, in many cases, the disease itself. The rest of the story has been reported in the newspapers. Cancer of the prostate can in many cases be controlled by the supply of female sex hormone or of synthetic substances with similar physiological effects.

What central planner, interested in the cure of cancer, would have supported Griffiths in his studies of the seasonal cycle of the hedgehog, or Grosser and Husler in their biochemical work on the lining membrane of the intestine?

How could anyone have connected phosphatase with cancer, when the existence of phosphatase was unknown? And while it was yet unknown, how could the man in charge of the cancer funds know to whom to give the money for research? How lucky it is for sufferers from cancer of the prostate that Griffiths and Grosser and Husler and the others were not doing cancer research!

The linking together of a toe-nail and an umbrella by a surrealist is scarcely more unpredictable than the linkings that result in big discoveries in science, and no planner could make the right guesses. The basic knowledge is what matters most of all. It is mostly made by people whose names do not appear in the newspapers and who get little financial support for their work. Who cares about the people who first gave us knowledge of *Penicillium*, for instance, and taught us to separate its species and varieties? Or who cares, indeed, about the people who first started studying moulds at all? They were probably regarded as cranks by the ordinary people of their time. The millionaires spill their money on clinical medicine rather than on the basic sciences that make clinical medicine a possibility. Luckily the research workers in the basic sciences will continue their research whether they have ample funds or not, because it is their life-interest. The real research worker does not refuse to find things out simply because no one will give him a cyclotron or ultra-centrifuge costing many thousands of pounds. It is not for him to demand more money, though he could use it. One thing, though, he needs. Let the worker in clinical medicine have a grand laboratory, by all means, and a large salary and whatever else he wants. But to the investigator in the basic sciences grant *freedom of inquiry*.

Chapter IV

SCIENCE UNDER TOTALITARIANISM

"It is possible to defend the false bases of Mendelism only by lies . . . the teaching of Mendel and Morgan I cannot call anything but false."—ACADEMICIAN T. D. LYSENKO.[60]

"When he grasps Bolshevism, the reader will not be able to give his sympathy to metaphysics, and Mendelism definitely is pure, undisguised metaphysics."—ACADEMICIAN T. D. LYSENKO.[60]

"In order to get a particular result, one must want to get exactly that result; if you want to get a particular result, you will get it."—ACADEMICIAN T. D. LYSENKO.[60]

"If young people are forced to study genetics, their ability to think will be damaged."—M. B. CHERNOYAROV.[60]

1. *The Growth of the Movement against Freedom in Science*

IN Britain, only about a dozen years separate us from the birth of the threat to freedom in science. An International Congress on the History of Science was held in London in 1931. A Soviet delegation, headed by Bukharin, attended. It was Hessen who expressed most explicitly the views represented by the delegation. He sought to show that Newton's researches were merely a by-product of the social and economic conditions of his country. It is not necessary to answer this contention in detail. Professor M. Polanyi [83] has reminded us that the same discoveries are sometimes made nearly simultaneously in countries where the social and economic conditions are radically different. During the nineteen-twenties those conditions were about as diverse as could be in India, the U.S.S.R., and Central Europe. The discovery of the Raman effect gained the Nobel Prize for the Indian, C. V. Raman, but it was independently discovered in the U.S.S.R. by Landsberg and also anticipated on theoretical grounds by the Austrian, Smekal, so that the term "Smekal-Raman effect" is sometimes used.

Despite the force of the criticism that can be directed against the views expressed by the Soviet delegation, Bukharin and

his associates sowed a seed which germinated. Two years later, at the Leicester meeting of the British Association, the germination of the seed began to become apparent: the attention of scientists began to become diverted away from science towards social and economic questions. The change was apparent in the Presidential Address by Sir Frederick Gowland Hopkins.[48] As he himself said, "You may feel that throughout this address I have dwelt exclusively on the material benefits of science to the neglect of its cultural value." In his final sentence, however, the great biochemist boldly stated his belief in the value of science as "one of the Humanities; no less."

The movement against the pursuit of science for its own sake and against freedom in the practice of science suddenly began to become influential in this country in 1936, when the economist, Sir Josiah Stamp, gave the Presidential Address to the British Association at Blackpool. Sir Josiah recommended a "wise central direction" to allocate research workers to their tasks.[92a] *Nature* followed the lead and the movement grew steadily. Science began to be regarded as simply the product of the material conditions of ordinary human life, and as existing only to affect those conditions. People began to claim that scientists cannot be left free to choose their own subjects for research, but must submit to central planning so that their work may be devoted to material human wants.

To fortify the British Association in its new movement, a special Division was formed in August 1938, the Division for the Social and International Relations of Science. This Division held a three-day meeting at the Royal Institution, London, in September 1941, throughout the whole of which I was present. The new movement was much in evidence at this meeting and there was a lot of political propaganda. The culminating event was the reading out by the President, Sir Richard Gregory, of *The New Charter of Scientific Fellowship*, consisting of a preface and seven *Scientific Principles*. "The basic principles of science," he read out as the fourth

principle, ". . . are influenced by the progressive needs of humanity." In this sentence, solemnly stated at the culminating moment of the conference and subsequently printed in *Nature*, [36] we have an approximation to the totalitarian idea of science. It is the very essence of true science that its basic principles are not affected by the needs of humanity. Those basic principles are the free search for demonstrable truth and the formulation of generalizations covering the discoveries made. The needs of humanity do not change them. It is only under totalitarianism that such a thing can happen. Let us recall Hitler's outlook on science (p. 38). "Science is a social phenomenon," he is reported to have said, "and like every other social phenomenon is limited by the benefit or injury it confers on the community. The idea of free and unfettered science . . . is absurd." [87] Let us recall also how Himmler thought it absurd for anyone to worry whether a document on German archæology were true or false, for the only thing that seemed to him to matter was whether it stimulated national pride. These sentiments are reflected in the British Association's fourth principle.

After the conference, people objected to the fourth principle and it was rewritten. The words "basic principles" were omitted and reference was made instead to the "structure" of science. [13] The obnoxious idea was thus replaced by a truism, for everyone knows that there is an interaction between science and industry. It has been claimed that the wording of the original statement was simply the result of careless drafting. It is likely that carelessness had much to do with the acceptance of the draft by the Council of the Association, but it is difficult to believe that some one on the drafting committee proposed the words "basic principles" when he did not mean them.

2. *War and Opinion*

It is true that totalitarianism was already beginning to have a bad influence on German science, when the outbreak of war

upset research in every country. Nevertheless, so high was the level of scientific culture in Germany that a sort of momentum carried it forward and prevented the political regime from interfering very seriously, apart from the expulsion of brilliant Jewish investigators. If peace had been preserved, there would probably have been a progressive deterioration in German science while the Nazis remained in power. In Russia there was never much momentum of scientific culture. Russian science as a whole was never comparable with German, despite the influence of a few distinguished men. When totalitarianism was applied to Soviet science, an opportunity was therefore given to observe its effects, undisturbed by any very powerful influence persisting from earlier times. To anyone interested in scientific method the experiment provides a valuable object-lesson, from which conclusions can be drawn as to the conditions that favour scientific research.

A study of Soviet science does not support the view that totalitarianism is favourable to science. It might seem churlish to criticize the institutions of our ally, when we all know that her action in self-defence has made our task in the war so much lighter. It would indeed have been congenial, even in a book devoted to the subject of the relation between science and totalitarianism, to omit all criticism of our ally, on account of the benefits that have accrued to us from the development and use of her military might.

Nevertheless, scientists who are supporters of the Soviet political regime have created a situation that makes it desirable, indeed necessary, that criticism should be offered. By pouring out a stream of praise for Soviet science in books, articles, and addresses they have created a body of opinion that could not have been formed if those who disagreed with them had felt free to answer. Now at last an answer must be made, for the swing of opinion, fostered by one-sided argument, threatens to have serious results for the science of democratic countries. If anyone censures the publication of adverse criticism of the science of our ally, let him direct that censure against those

who have traded on the unwillingness of others to offer such criticism. Truth cannot come from one-sided argument. Nothing but freedom of speech and publication can reveal it.

It cannot be right to praise the science of another country simply because that country is our ally. Good science is to be respected wherever it comes from; bad science, neglected or condemned. We rightly hear and commend the great music of German and Austrian composers. That we fight those countries is irrelevant. Similarly we should commend all that is good in the science of those countries. In commendation and censure our judgment should be unaffected by circumstances of alliance or hostility.

When the U.S.S.R. attacked Finland there was no outburst of praise for Soviet science in Britain. When Stalin made a pact with Hitler, *Nature* did not print columns of praise for the science of the U.S.S.R. But when Hitler attacked and thus made Britain and the U.S.S.R. allies, all those who believe in the central planning of science saw that their chance had come. They had everything their own way. Praise ot Soviet science poured forth in a stream. Public criticism of anything connected with the U.S.S.R. was made difficult, while praise could be given *ad libitum* (see p. 97).

The totalitarian idea of science has gained power as a result of the invasion of the U.S.S.R. by Germany. There are those who would have us believe that the success of the Soviet armies is evidence of the success of Soviet science. It is strange to reflect that there are people who say this, yet adhere to political groups which urgently opposed the rearmament of Britain. Six years ago they would have laughed, rightly, at the idea that military might is an index of scientific achievement. If military might were indeed such an index, then we should praise Nazi science above that of all other countries. German militarism is so efficient that nothing less than overwhelming odds in men and material will finally defeat it. An army is necessarily a dictatorship, not a democracy. As Walter Lippmann [67] explained before the war started, there

is one circumstance and one circumstance only in which totalitarianism is beneficial, and that one circumstance is war. If nearly everyone in a country has only one and the same intense desire, totalitarianism is the way to achieve it. The defeat of an enemy in war is just such a universally desired end. In peace, however, people's ends are extremely diverse, and as Lippmann said, the achievement of diverse ends is best made possible by a liberal regime. It is natural that totalitarian states which have long prepared for war should have greater military might than democracies which have not. This throws no light, however, on the question whether science prospers best under a totalitarian or a liberal regime.

One must remember, further, that only a small fraction of the whole of science is applicable to the intentional killing of human beings and to their defence against being intentionally killed. That is not the purpose of science. Nevertheless, in the application of science to these ends, Britain certainly did not lag behind any other country when once she went to war.

3. *Science in the U.S.S.R.*

The Soviet government has made great progress in applying scientific knowledge to practical ends. Russia was formerly backward in engineering. By importing foreign engineers and training new Russian ones the government brought part of the country into line with Western Europe in this respect. Indeed, the rivers being larger, larger dams were constructed, and some of the more spectacular engineering achievements are well known. That, however, is not what concerns us here. Does a totalitarian regime provide an environment favourable to discovery? Are intellectual standards in science high under such a regime? Those are the questions with which I am concerned.

In the early days of Bolshevism, scientists were to a large extent left alone. Looking through the scientific literature of the twenties, one finds some of the older Russian scientists

still producing work of the same kind and quality as before the revolution. Central planning was so much occupied with the economic sphere that science escaped and to some extent prospered. The great physiologist, Pavlov, continued his research. First-rate work, like that of the physicist Landsberg, was produced. Soviet genetics prospered. Nawashin, who had been working at cytogenetics since 1912, continued his research. Vavilov, who began to be productive in 1915, continued his important work and did much to increase our knowledge of the origin of cultivated grains. New workers joined the field. Nassonov [75] in St Petersburg (later Leningrad) and Karpova [58] in Moscow made important contributions to our knowledge of the Golgi element in cells. Pavlovsky, who had published some studies on the anatomy and physiology of scorpions before the revolution,[78] continued to publish on the same subject after it.[79] Soviet scientists were not prevented from working as individuals. Good and bad work was done, as good and bad work is done in any other country.

Then totalitarianism descended upon science in the U.S.S.R. The subject had for the most part escaped from the first five-year plan, but it was involved in the second. The old Academy of Science was remoulded as a central planning authority for science. A five-year plan for science was produced, covering the period 1932–37. Seven subjects were selected for investigation, as follows [18]:

(1) the structure of matter, and its bearing on astronomy, physics, chemical physics, and chemistry;

(2) the survey and utilization of the natural resources of the U.S.S.R.;

(3) the survey and planning of the power resources of the U.S.S.R.;

(4) problems of distribution, building materials, hygiene, etc., arising out of construction;

(5) the general introduction of chemistry in industry and agriculture;

(6) the study of biological evolution, and the bearing of its results on agriculture and materials for light industry;
(7) the provision of the historical and social theory for combating the ideas of capitalism, and dissolving the prejudices which survive in the minds of the people, and have been transmitted from earlier forms of society.

It is a strange list. The first item is so wide that chemists and physicists could receive no direction from it. The second, third, fourth, and fifth items are technological. The sixth directs biologists into one field only, that of evolution. It may be pretended that, since all organisms have evolved, all biological research is a study of evolution, but if so the item is so wide as to be meaningless. The seventh strikes curiously on the mind of a scientist in a democratic country, for instructions are given not only as to what shall be investigated, but as to what the results shall be. The list is a vivid illustration of the impossibility of planning scientific research. Either the subjects set must be so wide that it is futile to write them down, or else they must be so framed that they exclude the study of important branches of science. Both these tendencies are manifest in the list. Science can only progress rapidly if research workers are free to expand the bounds of knowledge wherever, at any given moment, they are expansible.

During the five years of the first plan for science, great strides forward were made in the outside world in fields from which Soviet scientists were excluded by the wording of the plan. Take almost any branch of non-evolutionary biological science in which outstanding discoveries were made in the outside world during the years of the plan, and you are likely to find that the whole subject was excluded from study. Sex hormones provide an example. The period of the five-year plan coincides with marvellous developments in that subject in Britain, the U.S.A., and elsewhere. The various hormones in their different forms were obtained as chemically pure substances and their structural formulæ determined. As a

culminating feat of all this wonderful progress, œstrone itself was synthesized from cholesterol. Meanwhile other substances were synthesized from inorganic materials, which behaved like hormones when injected, and exerted œstrogenic effects. That whole subject was excluded from the five-year plan. "The survey and utilization of the natural resources of the U.S.S.R.; the survey and planning of the power resources of the U.S.S.R. ; the problems of distribution, . . . etc., arising out of construction"; and so on: there is no place here for work on sex hormones. It is strange to think of Soviet scientists being tied down to such matters as "the provision of the historical and social theory for combating the ideas of capitalism," when so much of enormous interest and importance in real science was being done in the outside world.

Genetics tells the same story as endocrinology. In this subject also marvellous discoveries were made in the outside world during the currency of the five-year plan. We already knew that the chromosomes bore the genes responsible for inheritance, but the chromosomes usually looked much the same all along their length and never showed enough irregularities of structure to account for all the genes which were known to exist. There was compelling indirect evidence that the genes were strung out along the chromosomes in a line, and we even knew the order of their arrangement. Here, at this point on a chromosome of the fly *Drosophila*, we could say, is the gene which expresses itself most obviously by its effect on the shape of the wings; here, further along the same chromosome, is another affecting the size of the legs; further again is a gene affecting body-colour, and further still one affecting the size of the wings; and so on, for hundreds of other genes. But the chromosomes looked much the same all along, and naturally one wanted ocular demonstration.

That ocular demonstration has come, and in a totally unexpected way. It had been known since 1881 that certain large cells in the two-winged flies—cells of the salivary glands among others—have very extraordinary nuclei, with curious

cross-banded tapes inside. It was not until 1933 that Heitz and Bauer [45] showed what those banded structures are. They are giant chromosomes, about one hundred times the length of ordinary chromosomes. With a little stretching we can make some of them not a few μ long, like ordinary chromosomes, but nearly half a millimetre. Now, it will be said, we shall see the genes. Heitz and Bauer showed that the cross-bands differ in thickness, and that they are always arranged in the same order. If, in a certain part of a certain chromosome, there is a thick band and next to it a thin one, and then two thicks and then three thins and a thick, that same arrangement occurs in all the cells of normal members of the species. We knew from genetic evidence that the genes are arranged in a definite order: now we could see bands in the chromosomes arranged in a definite order, and so numerous that they might actually be the genes.

It was Painter [77] and his co-workers in the University of Texas who made the crucial discovery. There are certain individual flies in which some of the genes are known from the results of breeding experiments to be, as it were, the wrong way round. If we call the genes of one chromosome of a normal fly *a*, *b*, *c*, *d*, *e*, *f*, etc., in alphabetical order, there are some abnormal flies in which a part of the chromosome, say *l*, *m*, *n*, is arranged the wrong way round, *n*, *m*, *l*. The complex evidence for that was wholly indirect. Now Painter set out to look at the giant chromosomes of these abnormal individuals. What he found is one of the big things in the history of biology. The order of the bands was reversed in the corresponding part of the chromosome concerned. The last link in the evidence was forged and final ocular proof given of the chromosome theory of heredity.

These wonderful discoveries in cytogenetics deserve comparison with some of the greatest of physical science. They are mentioned here for a very particular purpose. They belong to a part of biology omitted from the five-year plan covering the period when they were made.

People may perhaps be inclined to reply that research was in fact done in the U.S.S.R. on some of these subjects despite their exclusion from the five-year plan. This is irrelevant to the argument, for it is the central planning of research that I condemn, not disobedience to central planning.

4. *The Soviet Genetics Controversy*

Not only did the five-year plan omit those very kinds of study which gave such momentous results: omission was not all. Soviet authority lent its aid to those very people who wished to eradicate the whole subject of genetics. That was the intention of Academician T. D. Lysenko and his associates at the conference held in 1939 under the auspices of the journal *Pod Znamenem Marxisma* (*Under the Banner of Marxism*). [60] The proceedings at that conference deserve to be better known, for they throw a strong light on the state of science under a totalitarian regime.

The chromosome theory of inheritance, as we have seen, was proved by ocular demonstration by Painter and his associates. It was one of the greatest scientific discoveries of the century, and the crowning achievement of cytogenetics. Let us hear the Soviet scientists on the subject. Lysenko says that "the only thing left from the so-called Morgan chromosome theory of inheritance is the chromosomes, and the whole theory of Morganism collapses." This is a short way of dealing with the great American scientist, T. H. Morgan, to whom cytogenetics probably owes more than to any other single man. I. I. Prezent [85] had previously written that cytogenetics should be thrown "into the archives of delusions."

The Soviet biologists by no means stop short when they have dealt with the chromosomes; it is the whole of genetics that Lysenko and his associates would destroy. ". . . I do not acknowledge Mendelism," says Lysenko; ". . . I do not consider formal Mendelian-Morganist genetics as a

science." He announces that he has made a public denial of the existence of the 3:1 ratio as a biological law. "It is possible to defend the false bases of Mendelism only by lies," he says; ". . . the teaching of Mendel and Morgan I cannot call anything but false." The great Danish geneticist, Johannsen, is selected for particular attack. "I quarrelled with Johannsen's theory," says Lysenko, "not because I dislike Johannsen himself, but because the Mendelians support his theory and make propaganda for him in our higher education courses."

V. K. Morozov rallies to Lysenko's cause. "The representatives of formal genetics say that they get good 3:1 ratio results with *Drosophila*. Their work with this object is very profitable to them, because the affair, as one might say, is irresponsible . . . if the flies die, they are not penalized." (This sentence is constructed sarcastically in a way which does not admit of a literal translation into English.) S. N. Davidenhov tells how famous doctors have advised him, "Stop bothering with genetics; the word heredity should not be mentioned."

A favourite way of attacking genetics was to say that it is metaphysical, though this charge cannot be substantiated by any valid argument. I. I. Prezent refers to Johannsen as "the classical representative of metaphysical genetics." "When he grasps Bolshevism," says Lysenko, "the reader will not be able to give his sympathy to metaphysics, and Mendelism definitely is pure, undisguised metaphysics." "The teaching of pure lines," says Professor L. N. Delonei, "is not free from metaphysics." The geneticist, Academician M. M. Zavadowsky, feels it necessary to answer the charge that the meaning of the words genotype and phenotype is metaphysical. Professor M. B. Chernoyarov concludes that "the chromosome theory of heredity is a metaphysical conception."

Openly political arguments are freely used for the purpose of attacking genetics, and Zavadowsky has to answer the accusation that "genetics inevitably, from its conceptions,

leads to reactionary ideas, to the race theory." Professor N. P. Doubinin has to discuss not only whether Mendelism "exists," but whether it "represents a product of the imperialist development of capitalist society." He speaks of "a reactionary attempt to replace the philosophy of dialectical materialism." "Of course," he says, "after its appearance Mendelism was perverted by the bourgeois scientists." Govorov's point of view is described as "gravely inimical to dialectical materialism." Lysenko says that it is dialectical materialism that makes him deny the Mendelian law of segregation. "We must proceed from dialectical materialism," says Professor Polyakov; "it is from this position that we must appreciate what genetics has contributed and what Comrade Lysenko has to offer." "Soviet biologists," says M. B. Mitin, the chairman of the conference, ". . . must master dialectical and historical materialism, and learn to apply the dialectic method to their scientific work."

The charges that genetics is metaphysical and that it is contrary to dialectical materialism are by no means the only ways of attacking it. It can be ridiculed, and palpably false arguments can be used. "Three take after papa," laughs K. A. Timiryazev, "one after mama, or *vice versa*, three after mama, one after papa." (Timiryazev evidently thinks that the 3:1 ratio appears in F. 1.) Lysenko refers to the 3:1 ratio as "devil's work." Professor Polyakov tells the geneticist N. I. Vavilov, "it was not necessary for you to humble yourself before foreign science." L. N. Delonei says that Vavilov "raves about the Americans."

Arguments against genetics are put forward which stand self-condemned. "The whole Soviet people," says V. K. Milovanov, "thousands of specialists and collective farmers who are doing wonderful work under his supervision, are with Lysenko." The "small wilting group" of geneticists is "cut off from practical life." "In order to get a particular result, one must want to get exactly that result," says Lysenko; "if you want to get a particular result, you will get it." (These

words were quoted by U. Y. Kerkiss, and Lysenko interrupted his remarks to confirm their correctness.)

The teaching of genetics was condemned by several speakers. "It is essential to remove the teaching of genetics from the secondary school," says Academician A. F. Yudin. "If young people are forced to study genetics, their ability to think will be damaged," remarks M. B. Chernoyarov. "To this day we have chairs of genetics," says V. K. Milovanov; "they should have been liquidated long ago."

The conference lasted seven days. Throughout, the word "Darwinism" was used in a special sense in which it is never used, so far as I know, outside the U.S.S.R. Apparently it means roughly what the outside world calls neo-Lamarckism, but it is difficult to be certain. Members of both camps—those who attacked and those who made a prudent defence of genetics — strove to show that they were genuine "Darwinists" and that their views accorded with dialectical materialism. The level of the discussion was very low. Scorn was thrown on the use of statistical methods. The opponents of genetics never got beyond the 3:1 ratio, except that in one place Lysenko mentioned the 1:2:1 ratio. It is as though a modern discussion were being held on the structure of the atom, and one party never got beyond the proportional combining weights of the elements and spent their time denying the "existence" of these proportions.

The party which attacked genetics, headed by Lysenko, is the one favoured by Soviet authority. This man is not only an Academician, but also the Director of the Academy of Agricultural Science. At his suggestion the Commissariat of Agriculture issued an order compelling workers at all agricultural research stations to carry out their work in accordance with Lysenko's belief in the inheritance of acquired characters (or, more precisely, in the absence of distinction between phenotype and genotype). The Soviet authorities also stopped the publication of translations of foreign books on genetics. These facts were recorded at the conference by N. I. Vavilov.

The report of the conference was reviewed in *Nature* by Mr P. G. 'Espinasse.[29] Anyone reading the review would conclude that for the most part the discussion was learned and concerned with highly technical problems. This is misleading. Mr 'Espinasse notices that argument does not get beyond the 3:1 level, but he passes this off by saying that the speakers used the term 3:1 ratio as standing for every ratio possible in genetic theory. A careful reading of the report leads me to reject Mr 'Espinasse's opinion, and to conclude that the arguments against genetics stood at a low level of scholarship because those who used the arguments had only an elementary acquaintance with the subject. Many English-speaking scientists probably have little knowledge of the conference and it is therefore desirable that the whole report should be published in English, so that British and American scientists may judge for themselves.*

Mr 'Espinasse allows that some of those who attacked genetics at the conference "made it quite clear that they did not understand what it was that was being discussed." Among the people who offered to produce desirable varieties of plants and animals, he says, were some who were "honest, ignorant, and useless" and others, "possibly to a considerable extent, consciously fraudulent." These few words do not suffice to present to readers a true picture of the low standard of scholarship exhibited at the conference.

The main lesson to be drawn from the Soviet genetics controversy is that science can flourish only if free from state control. Professor M. Polanyi has particularly emphasized this point in his article on "The Autonomy of Science,"[84] which deserves to be read by every scientist. If the selection of scientific personnel is left to the state, the wrong men are likely to be given important posts, because those who are not

* A translation has been made for the Society for Cultural Relations with the U.S.S.R., which has been available to me. The translation is useful, but it has not been made by a geneticist and is not very literal in places. The School of Slavonic and East European Studies has kindly made the original Russian version available to me.

themselves scientists will be led astray by the false claims and pretences of ignorant and foolish persons. As we have seen, such persons may even become academicians and be given wide powers to control scientific research. Worse still, scientists may exhibit a servile obedience to their political bosses and let dogmas and slogans affect their science.

5. *The Deficiencies of Soviet Science*

The impression that Soviet science is great tends to be fostered by continual repetitions of praise. The same discoveries are praised repeatedly, while greater discoveries made in non-communist countries go without mention. One could take almost any European country and find things to praise in the scientific work done there, as well as excuses for shortcomings. If one went to that country, visited various laboratories and chatted with the research workers, one could come back and write an enthusiastic account of what one had seen and heard.

No one will deny that good scientific work has been done in the U.S.S.R. since the inauguration of the five-year plans for science. Excellent work has been done in ecology, for instance, by D. N. Kashkarov, N. I. Kalabukhov, G. F. Gauze, and others. My friend Mr Charles Elton tells me that Soviet ecological research has been on the whole similar to that of Britain and the U.S.A., except that the Soviet ecologists have very poor statistical training and judgment. Other subjects in which good research has been done will occur to specialists in various fields, and some of them have been so much advertised that they are generally known. Many countries, however, produce good science, and it would be false to pretend that Soviet scientific research as a whole would bear comparison with British or American, whether one looks especially for particular excellence or absence of particular weakness. One may argue, of course, that the particular circumstances of the U.S.S.R. after the revolution made it

necessary to concentrate on applications and to regard research in science as of less importance. If this argument be accepted, one should still withhold praise where praise is not due.

Even the most enthusiastic writers about Soviet science have to admit its deficiencies. Sometimes it is done very mildly. Dr J. Needham tells us that when he visited Russian laboratories in 1935 "the general standard of work was not quite up to the prevailing standards in Western countries, or in the United States," but he hastens to prophesy rapid improvement.[76] Dr D. Shoenberg allows that "there seemed to be a good deal of unnecessary red tape" in the Institute of Physical Problems in Moscow, where he worked in 1937–38; and he remarks on the difficulty of getting things for use in scientific work, which one could buy at Woolworth's in Britain. He complains also of "a rather too literal interpretation of planning, in the sense of too slavish a copying of the type of plan suitable for industrial production." He allows that "there have as yet been no really revolutionary developments of importance comparable with Rutherford's work on the atom, or advances in the technique of physics of importance comparable with Lawrence's invention of the cyclotron." He writes also of the uncritical attitude of Soviet physicists and their "over-easy acceptance" of their own conclusions.[92] Dr A. Walton writes that much of the research in the U.S.S.R. was "at first somewhat immature and even primitive."[107] Mr J. G. Crowther[19] says that the young scientists are still "immature." Some Soviet scientists, he admits, denounced scientific theories because they were advocated by persons whose political views were regarded as inimical to the state. The scientific researches of persons disapproved by the political authorities have sometimes been omitted in lists of references, he says, and scientists have sometimes been seen apologizing to the political authorities for having held opinions which appear to the majority of the scientists in the world to be correct. Many scientists have been imprisoned and some shot. Elsewhere[20] Mr Crowther says that the Soviet system

has produced "tens of thousands of new young scientific workers, many of them somewhat raw and not yet old enough in tradition to have highly developed scientific intuitions and critical judgments, but superb material for flying and artillery officers and factory management." Professor J. D. Bernal [10] says that it would be "idle" to look for "quietly pursued excellence and sound and acute scholarship" in the U.S.S.R. Elsewhere [8] he writes of the "shortcomings and backwardness of Soviet science," and elsewhere again [9] of "the errors and the crudities of Soviet science."

These quotations are from those who write in *praise* of Soviet science. It is legitimate to ask whether the same authors would have written in praise of something so admittedly open to adverse criticism, if it had been the product of a democratic state.

Those who praise Soviet science are not ashamed to use directly contradictory arguments. On the one hand, they extol the virtues of the central planning of research, and pour scorn on the individualist who wants to choose his own subject. They ridicule the study of pure science, and say contemptuously that they do not recognize a part of science as "impure." All this, of course, is the central theme of those who praise Soviet science. The same people, however, use arguments which flatly contradict their main contention.

Mr J. G. Crowther, in his *Soviet Science* (Kegan Paul, 1936), [18] tells us on pp. 192–193 that in England "the majority of chemists are too much restricted to immediate problems . . . the chemist in the Soviet Union is much more free to choose the sort of problem he would like to investigate. If he wishes to undertake fundamental research, he is encouraged. In England there is far too much control by authority: the chemist is too frequently expected to attack problems chosen for him by his superiors." These statements are made on the authority of a British scientist who worked in the U.S.S.R. On pp. 87–88 Mr Crowther tells us exactly the opposite, in discussing "The most original feature of Soviet laboratory

organization," the central planning of research. This he illustrates by the example of the Kharkov Physico-Technical Institute. He explains that the plans for research, drawn up by a central authority, "must receive adherence in principle from every research worker. . . . They are guides which prevent any worker from being uncertain what problem he should be attacking. The research worker cannot change the subject of his researches without wide discussions by the staff of the institute. . . . The personal desires of the individual members of a brigade receive little consideration . . . the Soviet research worker does not count much as an individual." The central planning organization for the whole of Soviet science is the Academy, whose first duty is "to plan and direct the study and application of science towards the fulfilment of socialist construction, and the further growth of the socialist order" (p. 24). Now which of these stories is true? Is the research worker free to choose what he will study and is he encouraged to undertake fundamental research, as stated on pp. 192–193, or is the exact contrary true, as stated on pp. 87–88?

There has been much propaganda for Lysenko's methods of controlling the time of germination of seeds, and people might be led to think that "vernalization" was a Soviet discovery. An American scientist tells us, however, that the discovery was made in the United States before the Civil War.[91a] The principle was certainly firmly established by Braem in 1890, in connexion with the germination of the resting reproductive bodies of animals.[11a]

Every country produces poor as well as good science, but the U.S.S.R. has produced an unduly high proportion of bad and suspect science, such as the work on the artificial control of the sex ratio and on "mitogenetic rays." It is fair, however, to add that the existence of these supposed rays has been denied by certain Soviet workers as well as by the scientists of the outside world.

It is difficult to assess the scientific achievement of one

country in comparison with others, but the following method was devised for the purpose of getting some unbiased information on the subject. I asked seven scientists to prepare a list of the two dozen most important scientific discoveries made between the two great wars. I gave them no hint of the reason for my request. They are all lecturers in science at Oxford, who themselves carry out scientific research in the University Departments of Physical Chemistry, Organic Chemistry, Botany, Zoology, and Physiology. They provided me with a list of twenty-seven items. The list is as follows. (Three of the items are inventions rather than discoveries.)

Schrödinger, Heisenberg and Dirac on quantum mechanics.
Rutherford on the structure of the atomic nucleus.
Aston on isotopes.
The Braggs, Goldschmidt, Debye, Bernal and Astbury on molecular structure as exhibited by X-ray diffraction and other physical methods.
Langmuir on molecular forces as exhibited by the study of surface films.
Curie-Joliot on artificial radio-activity.
Lawrence on the cyclotron.
Bush on the electron-microscope.
Svedberg on the ultra-centrifuge.
Sidgwick and Pauling on molecular structure and valency.
Carothers on high polymers.
Haworth on the molecular structure of carbohydrates.
Karrer and Kuhn on carotenoids.
Szent-Györgyi and Williams on the isolation and synthesis of vitamins.
Northrop on crystalline enzymes.
Freundlich on colloid chemistry.
Stanley on virus diseases.
Went on plant hormones.
Fisher, Haldane, Timoféëff-Ressovsky, Muller and Darlington on the genetical theory of evolution and allied subjects.

Spemann on chemical factors in animal development.
Vogt on cell-movements in animal development.
Dale, Loewi and Feldberg on the chemistry of nerve action.
Landsteiner on serological differences between individuals.
Domagk on sulphonamides.
Fleming and Florey on penicillin.
Cook and Kennaway on carcinogens.
Fisher on the statistical treatment of small samples.

Different groups of scientists would have produced different lists, but a good proportion of the items are, I think, almost inevitable. The striking fact about the list is that it contains no mention of Soviet science. So far as I know, there has been little or no propaganda for British, American, or German science, and it is interesting to find that all the propaganda for Soviet science has not resulted in the inclusion of a single item from the U.S.S.R. Muller, it is true, did part of his work in that country, but he is an American who made his fundamental discoveries in the University of Texas before he went to Russia. Timoféëff-Ressovsky did some of his early work at the Institute of Experimental Biology in Moscow, but the research for which he is famous was done at the Kaiser Wilhelm Institute in Berlin. The list suggests what is likely to be the general opinion among scientists, namely, that Britain, the U.S.A. and Germany were pre-eminent in scientific research in the period between the two wars; though there is strong evidence that totalitarianism was beginning to have a detrimental effect on German science in the thirties.[36a]

It might be thought that I chose seven scientists who were politically biased against the Soviet Union and were therefore unable to make a fair selection (despite the fact that they did not know the purpose of the list until it was made). For this reason I mention that I chose two socialists among the seven. Of the others, two adhere to no party, while the political views of the remaining three are unknown to me.

Those who praise Soviet science are sometimes almost

pitifully anxious to make the most of small discoveries. Thus the distinguished Soviet scientist, Dr Peter Kapitsa,[57] in a general survey of science and war in the U.S.S.R., tells us that Soviet scientists are experimenting with a synthetic drug which is likely to have curative properties "not inferior to those of Peruvian balsam." This is his only claim for Soviet pharmacology. Balsam of Peru is still sometimes used in the treatment of wounds. It was introduced into European medicine by Nicholas Monardes of Seville in 1560.[34] Monardes would have been flattered if he could have realized that nearly four centuries later the preparation of a "not inferior" substitute for his balsam would be used in propaganda on behalf of a large country. Meanwhile scientists in Britain were at work on penicillin. There has been too much boosting of discoveries at the level of a substitute for balsam of Peru.

6. *Party Politics and Free Science*

The movement for free science and pure science is not political in any narrow sense. It includes liberals, conservatives, and socialists. That is as it should be. It goes without saying that liberals favour free science. Conservatives want to conserve what they think good in existing institutions, and those of them who think free science good naturally want to conserve it. There is, I think, no essential element in socialism opposed to the ideas that pure science has value as an end in itself, that technology must have science as its basis, and that science prospers best when research workers are free. It is only from believers in totalitarianism that we can expect no support. The central planning of science is essentially part of the totalitarian theory of the state.

Chapter V

THE DUTIES OF SCIENTISTS TO SOCIETY

"The philosopher * should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biased by appearances; have no favourite hypothesis; be of no school; and in doctrine have no master. He should not be a respecter of persons, but of things. Truth should be his primary object."—MICHAEL FARADAY, scientist.[31]

1. *Introduction*

SCIENCE is necessarily a social activity. It is true that the research worker is often rather a retiring person, finding little pleasure in the kinds of social life that mean so much to others. Nevertheless, that his work is social is shown by the necessity for demonstrable proofs. This necessity presupposes the interest and participation of others. The person who makes a systematic collection of natural objects simply for his own satisfaction, without adding to the common store of knowledge or infusing others with his interests, is not a scientist. It is true that the scientist's motives may be and often are mixed. Unless he has an intense internal urge to find out, to try to satisfy an insatiable curiosity, he will not be much of a research worker. Still, his work must be presented in a form in which it will influence the opinion of others.

Although no one should be forced to disclose his results before he has satisfied himself that they are fit for publication, yet there ought to be no private property in demonstrable knowledge. If a scientist keeps his discoveries to himself, his activities are unsocial and indefensible; for knowledge is good, and it is better for many than for one person to possess it. Every scientist lives a vastly fuller life just because generations of other scientists have not kept their discoveries to

* Faraday's word for scientist.

themselves. To profit from the work of others without making the return that is within one's power is indefensible.

Newton has often been charged with secretiveness, but perhaps his case has been rather misrepresented. It is true that he did not hurry to get his discoveries printed, but this was largely because of his great dislike of controversy. He was elected a Fellow of the Royal Society at the age of twenty-nine. Five days before his election he wrote to the Secretary saying that if elected "I shall endeavour to testify my gratitude by communicating what my poor and solitary endeavours can effect towards the promoting your philosophical designs."[95] He was by no means slow in keeping his promise. Exactly a month later he sent to the Secretary his famous paper on the composition of white light, which he showed to be made up of a spectrum of different colours, which were refracted by glass to different degrees. It was the reception of this paper that turned him in upon himself and made him so secretive. Professor Linus of Liége, failing to understand Newton's experiments, criticized them stupidly in a paper published in the *Philosophical Transactions* of the Society. Unfortunately, the Secretary pressed Newton to reply. The matter dragged on for years, Newton refusing to answer because he thought that Linus had not taken the trouble to understand what was clearly explained in the original paper. Finally Newton became exasperated. "I see I have made myself a slave to philosophy," he wrote to the Secretary, "but if I get free of Mr Linus's business I will resolutely bid adieu to it eternally, excepting what I do for my private satisfaction, or leave to come out after me; for I see a man must either resolve to put out nothing new, or to become a slave to defend it." Newton did not stick to his threat, but this incident certainly made him more secretive; and science would have profited even more generously than it did from his genius if he had been readier to publish his discoveries.

The primary duty of the research scientist, as such, is to make the greatest possible public contribution to demonstrable

knowledge. He generally requires no advice from anyone on the subject of his primary duty, for he knows better than others how his own particular qualities can be used most effectively. There are some pitfalls, however, which may be regarded as of a moral kind, even in the accomplishment of his primary duty. He must be on his guard against lazily drifting into trivial work, limited in significance and unlikely to open new fields of investigation or help others in their research. Although he must make full use of working hypotheses, yet he must avoid the fascination of idle speculations. He must never depart from truth for convenience, as when a systematic biologist leaves unchanged a classification of organisms which he knows to be unnatural, simply because a particular grouping is usual or convenient. He must avoid the temptation to follow a course simply because it is fashionable, or likely to bring him praise because it is immediately connected with practical affairs, when he knows that his own particular talents enable him to discharge his primary duty better in another way.

The discharge of this duty is something in which the investigator finds pleasure. It may therefore be asked whether any extra or secondary duties are owed by the scientist to the community in return for being allowed to do what he likes doing; for many people have uncongenial employments which they would give up at once if they were made financially independent.

It must be remembered that the research scientist has often obtained his position in society by voluntarily giving up highly prized pleasures in order to devote himself to laborious study. No scientist is likely to get far whose spare time is all spent in frivolous amusement, or whose study is always devoted to those subjects that are immediately attractive to him. He knows that he must master certain difficult subjects, although he finds them unattractive, in order that he may understand better the subject of his choice. He voluntarily disciplines himself to study while others seek ephemeral amusement, and devotes himself to hard and uncongenial tasks. This discipline he imposed on himself when young,

even while still a boy; if he had not done so, he would probably not be a research scientist. The recurring disappointments of research and the unavoidable tedium of certain parts of it must also be remembered. The community, then, should not thoughtlessly demand extra services of the scientist. Nevertheless, he often asks himself what services he can render to the community as a whole, apart from his primary duty; and the general congeniality and liberty of his task under the conditions of free science make him ask himself this the more insistently. The teacher of science, whose primary duty is to instil the spirit of science and to convey factual knowledge, will ask himself the same question.

When confronted with this ethical problem, the scientist may reach either of two conclusions. On the one hand, he may decide that his best contribution to human welfare may be made privately in the circle of his own acquaintance. He may believe that social evils will continue as long as people rely on politics and propaganda for human betterment, and that the only hope for progress lies in the voluntary improvement of the relations between those who come into direct contact in the ordinary course of their lives. He may have been impressed by the low moral standards of many politicians and propagandists, and by the solid good done inconspicuously by good men and women. On the other hand, he may consider that his special qualities as a scientist give him the privilege of a wider and special scope for good.

It is for the scientist himself to judge between the two courses. His temperament must be the deciding factor. If he chooses to limit himself to private action the decision is perfectly proper, and it would be an impertinence to deny him the right to make it. In that case there is no advice that a scientist can offer. If, however, he decides that he will use his special qualifications directly for the public good, apart from his primary duty, then certain observations may be offered, which will occupy the rest of this chapter. These observations are intended to indicate some of the accessory

ways in which the scientist can serve his fellow-creatures. Anyone who makes suggestions on this subject lays himself open to the charge of being an unqualified moralist, and the task is not undertaken without diffidence. Nevertheless, it is urgent that some one should undertake it, and the very defects in what I shall write may prompt better-qualified people to improve on my suggestions. Those who think that science should be centrally planned are undeterred by doubts as to their qualifications to give advice on ethical subjects. They have spread powerful propaganda intended to make scientists believe that they have three social obligations: to devote all their energies to the solution of the problems of man's material wants, to accept central planning in their own subject, and to press for the adoption of central planning of society as a whole. This, so far as one can make out, is what is meant by the social responsibilities of scientists, as the term is usually used. Scientists who have other ideas about their social responsibilities have not yet bothered to challenge the propaganda, which is effective because it is not answered.

2. *Science and Evil*

The scientist is often charged with being responsible for much of the misery and unhappiness in the world, because his discoveries help the engineer to devise and construct the weapons of modern war. When people reflect on human miseries, they are apt to think first of those of war, and it would be futile to seek to minimize them; yet it is doubtful whether they are the most intense. The person bereaved, wounded, or dying in war has the moral support, the fellow-feeling of his compatriots. The sufferer from incurable disease, again, has at least the relief that comes from the knowledge that friends, doctor, nurses—all with whom he is in contact—strive hard to lessen the suffering. Far more intense is the misery of those who are persecuted by authority for racial or political reasons. The concentration or penal

camp, the activities of the secret police (whether it be Gestapo, Ochrana, or Ogpu), the totalitarian purge—these are surely the greatest evils of mankind, by which individual human beings, because their beliefs and ideas differ from those of a central planning authority, are taken away from everyone whom they hold dear, kept under conditions of appalling cruelty, repeatedly subjected to questionings and to threats directed at relatives, and finally, in many cases, either executed after a so-called trial, shot in prison without even that, or killed through exposure to intolerable conditions.[59, 69, 99, 100] These evils are the greater because of the huge number of people who have suffered them. They are probably the greatest evils known to man, and no part of them can be ascribed to the discoveries of science.

Man's deliberate inhumanity to man, which is probably the chief cause of intense suffering, is something for which the scientist is not responsible; though as knowledge of psychology grows he may become able to lessen it. Ruthlessness is a characteristic of totalitarian but not of democratic states, and psychologists may one day be able to prevent ruthless cruelty by discovering the causes that make people accept totalitarian government. Again, cruelty is often the result of hate engendered in childhood, and a better understanding of child psychology may reduce the amount of hate in the world.

Scarcely anyone will deny that modern war is a terrible evil, and there are those who would charge scientists with the responsibility. It is suggested that an urgent duty of scientists is to make sure that their discoveries are not used for destructive purposes, especially in war. This, however, would make scientific research impossible. Professor P. W. Bridgman,[12] of Harvard University, has stressed this point. If, as he says, the scientist were required to make only those discoveries which could not wilfully be perverted to harmful uses, he would almost certainly feel himself so restricted that he would make no discoveries at all. It is impossible to foresee all the consequences or to balance the good consequences against the

bad. There is no mechanism by which the scientist can control the consequences of his discoveries. As Professor Bridgman says, it is society as a whole that is in a position to provide the mechanism of control rather than the individual discoverer.

Again, the fact that greater numbers of people are killed in modern than in ancient wars is due not so much to the greater effectiveness of modern offensive weapons (for defensive devices are evolved to meet them), as to modern methods of sanitation and transport, which enable vast numbers of people to congregate together in cities or armies and to be killed in huge numbers. Even if technologists did not invent explosives, and soldiers relied on clubs and swords, huge numbers of people would nevertheless be killed in modern war. Nearly everyone, incidentally, would rather be wounded or killed by a bullet or shell than by a bayonet or sword. The person who condemns science because of its relation to war must be prepared to abandon modern sanitation and transport, the chief causes of huge casualties.

3. *Some Secondary Duties*

So much for the negative aspect of the problem. We have discussed the evils for which the scientist cannot be held responsible. What good can he foster and what evils can he prevent?

First comes the preservation of our scientific heritage. Chapter II was devoted to the values of science. We have seen that knowledge has been built up by people who valued it as an end. Some of our younger scientists, affected by propaganda, are ready to let central planning and a crudely materialistic outlook supplant the freedom and idealism that have made science great. Our scientific heritage is threatened. Let us understand that science is not our private fortune, to squander as we will. It is a heritage that is entailed to future generations, and we should preserve it and add to it as much as we can before we pass it on.

Science is not simply a mass of demonstrable knowledge about nature recorded in books and journals. That is not in danger, for there is no threat to burn our scientific records. The part of our heritage that is threatened is the spirit of science. Little has been written about that spirit. As Professor Michael Polanyi [84] has remarked, it is something that cannot easily be communicated except by personal example. It is only a few centuries old, apart from vague beginnings such as we see among present-day savages and sporadic appearances in concrete form throughout the historical period. There is no certainty that it is immortal. Only ignorant and thoughtless people can take it for granted, or imagine that they would have possessed much of it if they had not received it from others. Here is a field in which research workers, as well as students and teachers of science in schools and universities, can render a great service to the community. We can all work to maintain and enlarge the belief in the value of science as an end.

We can do much to preserve our scientific heritage. We can dispute openly with those who profess to see nothing in science except an easier supply of food, shelter, health, and leisure. As we saw in Chapter II, it is fantastic to suppose that while music and art are ends, science is not. We should urge young scientists with real aptitude for science itself to resist the higher salaries that will be held out to tempt them into technology. We should do everything in our power to make as many people as possible understand that science is an end.

That brings us to our second social responsibility. If science is good, then the greater the number of people who enjoy it, the better. There is scope for the encouragement of amateur by professional science, a subject to which I have devoted a chapter of another book.[6] The amateur, by definition, is one who values science as an end and thus possesses the scientific spirit. In the past the contributions of amateurs to scientific knowledge have been enormous, and even in modern times excellent research is carried out by amateurs, especially in biology and geology.[6, 103] There are amateur

scientific societies of high standing, such as the Quekett Microscopical Club, and the Malacological and Conchological Societies. Amateur science presents a field in which suitable professionals can help both amateurs and themselves, to the advantage of science; though it must be admitted that certain pitfalls present themselves. If the professional who finds happiness in the direction of others co-operates with amateurs merely by collecting round him a group of unpaid helpers who like being told what to do, there may be satisfaction of various psychological urges on both sides, but little progress in science is likely to come of it. The professional who wants to co-operate genuinely in this movement must put aside feelings of authority and condescension, and be as ready to learn as to teach and direct.

It is unfortunate that love of science scarcely exists to-day among the poorer classes of society. It was not always so. One thinks at once of Hugh Miller, the Scottish quarryman who observed the rocks and went on to become the author of *The Old Red Sandstone*, a classic now reproduced in Everyman's Library.[73] Miller was not unique. Parallel to his life-story runs that of a man immortalized in the name of *Peachia*, a remarkable genus of sea-anemones. Charles Peach was a very exceptional man. He had four shillings a day, a wife, and nine children. He was only a private in the mounted guard (preventive service) at an obscure part of the Cornish coast.[55] I have not been able to discover exactly what it was that he was paid four shillings a day to prevent, but I do know that in his spare time he was a first-rate marine naturalist. Annually he attended the meetings of the British Association and mixed on level terms with the best contemporary biologists. Men of his calibre seem to have become nearly extinct. Peach shows that poverty is no bar to the study of science, but as wealth becomes more evenly distributed it ought to become increasingly easy to spread a love of science through all sections of the community.

The third social responsibility of scientists follows naturally

on the second. They should take steps to facilitate the entry of suitable people of all classes into the profession of science. It must never be forgotten that genius and talent have sprung from every class, and that it is wasteful to let any potential talent remain unrecognized as a result of lack of opportunity. The scholarship system will bring a lucky and precocious child to the university without cost to the parents, but that is not enough. We need some comprehensive arrangement for bringing suitable children—and men and women of all ages too—into personal contact with first-rate research workers. Nearly every successful scientist can recollect some early incident in which his enthusiasm was first kindled. Many potential scientists in all classes of society probably go through life without ever experiencing such a kindling of enthusiasm. Something could be done if those who owe their position and success in science to such an incident were to give the same kind of help to others. It is doubtful whether popular books, radio talks, and public lectures fill the need (though it was a public lecture that started Benjamin Franklin on the course of action which made him become one of the world's foremost physicists through spare-time work). For adults the W.E.A. is, of course, in many ways excellent, but it probably serves to transmit factual knowledge rather than the spirit of science. The transmission of that spirit can usually be best effected by informal personal contact between the potential scientist and some one in whom intense enthusiasm has already been awakened. Here is a field in which scientists who have the necessary human understanding can quietly and unostentatiously do good not only to those whom they inspire, but also indirectly to the whole community.

Right through the history of science, people in a position to do so have noticed and encouraged talent. One has only to think, for instance, of what the Duke of Brunswick did for the bricklayer's son, Johann Gauss, and through him for science and humanity. As we move towards a healthier society in which great wealth and poverty will no longer co-

exist, so the kind of help necessary will change. It is still true to-day that the child born in the richer classes has a great advantage, for it is generally much easier for him to get into personal contact with first-rate research workers. This is wrong and wasteful, and scientists have it in their power to correct the error.

Beyond those who could be inspired to great heights in this way, there are others who have the spirit of science but not the kind of mind that makes for academic success. There is scope for another entrance to the world of science than that which leads through the examination-room. It might be profitable to reform altogether the status of the laboratory assistant. At present assistants tend to be recruited in a haphazard way. The senior assistant often suggests to a parent that a boy should join the laboratory staff, without anyone considering whether the boy himself has any real feeling for science. Such boys sometimes fail to get that feeling, while others develop it gradually and not only become first-rate in their work, but have the satisfaction of living full and worth-while lives. What is wanted is some scheme whereby people can become laboratory assistants because they want to be scientists. This would be linked to a scheme enabling them to pass on eventually, if suitable, to independent research. Famous scientists like Faraday and Rühmkorff have forced their way into the world of science by beginning as laboratory assistants, and the process still happens to-day; but science would be well served if this entry into its ranks were made less fortuitous. The whole status of the laboratory assistant could be improved, and people of all classes encouraged to enter the scientific world as assistants because they felt that their real life-interest lay in that subject.

4. *Science and Politics*

The fourth social responsibility of scientists is in relation to politics.

The scientist knows how small the uncertainties are in his own sphere compared with the uncertainties of political doctrines; yet he knows that the scientific outlook changes radically as a result of new discoveries. This teaches him not to be a dogmatic adherent to any political party, and it also teaches the much profounder truth, that the irreversible must above all be avoided. The scientist knows that again and again he and other scientists are wrong in the conclusions they draw from factual evidence. He knows also that it does not matter, because nothing irreversible has happened as a result of his wrong conclusions. He is always ready for change. In politics, therefore, where everything is much more uncertain, he must raise his voice against all irreversible decisions, or decisions reversible only by bloody revolution. He is willing that any form of government whatever should be tried, provided that it can easily be reversed if people find, on free and open discussion, that they do not like it. For this reason it is consistent with the scientific outlook that he should oppose all tyrannical monarchies, such as that of the Czars, and all totalitarian regimes, whether national socialist, fascist, or communist. He may be a liberal, a conservative, or a socialist in his political views, or may hold any opinions whatever on economic matters; but if he is determined that, once his policy is put into practice, nothing but a warlike revolution shall change it, then he has left the scientific spirit behind him in the laboratory.

In order that social conditions may be continually improved by change, two principles of sound politics must above all be defended, and they are both principles upon which the scientist puts the highest value in his own sphere. They are the principles of free speech and valid argument. The first

existed in peace-time Britain: the second has never flourished but is a necessity for real progress.

Not only has freedom of speech and publication failed to penetrate into powerful countries, such as Russia, where it never existed, and been ousted from others, such as Germany, where it seemed reasonably secure, but even in Britain there is a danger that it may not be restored after the war. We hear to-day the argument that economic liberty is more important than liberty of speech, an argument whose logical unsoundness does not prevent it from having a certain vogue. Even scientists, who see as clearly as anyone else that this freedom is of paramount importance if truth is to be attained, are willing to be equivocal on the subject where politics are concerned. Professor L. Hogben, for instance, writes thus: "If the functions of democratic government were still as when Milton claimed the right to know, to utter and to argue freely according to conscience, they would be equally important to-day. They are not."[46] Although it seems uncertain what the word "they" refers to in these sentences and the exact meaning is therefore not clear, yet this passage must apparently be taken to be a statement by a scientist directed against the necessity for freedom of speech in politics. Scientists would do well to register dissent from such views. In time of war, there has to be some limitation of freedom of speech and publication, but that is precisely because it is essential during war that the truth about secret military matters should not be known: thus the exception proves the rule. Whoever argues against freedom of speech does not wish the truth to be known.

There is one serious aspect of the subject of freedom of speech that is commonly overlooked. It is the support given to the cause of free speech by those who only want to use it to gain power and thus be in a position to eradicate it. That free speech is desirable is a liberal idea, directly contrary to communist theory and practice; yet communists support both the National Council for Civil Liberties and The Radio Freedom

League. That real believers in free speech should collaborate with those who wish to eradicate it is deplorable. Nothing would be easier than to prevent the adherence of dissimulators to causes in which they do not believe. Societies concerned with freedom of speech could require a signed statement from adherents that they believe in freedom of speech as a permanent safeguard of progress, and not as a temporary expedient to be cast aside when it has served the purposes of a party.

No freedom is so important as freedom of speech, for if that is free, other curtailments of liberty can be made known and redressed. With free speech, no period can be utterly stagnant, even when an unprogressive party is in power; for the circulation of new ideas will never stop so long as speech and publication are free.

The censorship on publication about the U.S.S.R. in the periodical Press, and the general acquiescence in that censorship, are among the most disturbing features of contemporary Britain. There is more than acquiescence. Even a formerly liberal paper, the *News Chronicle*, protests indignantly at the least criticism of the Soviet regime, when one would expect it on the contrary to be demanding the fullest right of every citizen to express his opinion. The method by which the censorship is exerted has not been fully explained to the public, but of its existence there is no doubt. For instance, the editor of the scientific journal *Endeavour* asked me to contribute a letter to "start a hare." I accordingly wrote a letter, urging the necessity for freedom in science and suggesting that the success in war of the totalitarian states, Germany and the U.S.S.R., should not make us think of totalitarianism as a progressive force in any other sphere. The letter was put into type and a proof sent to me. However, when the letter appeared in print, I found that the editor had rewritten part of it without my permission, so as to exclude the reference to the U.S.S.R. as a totalitarian state.[7] He had substituted other words of his own, not conveying the same message. When I protested, he answered that "we were assured in quite un-

ambiguous terms that the original wording would not get by the censorship, and so had to bow to necessity." The editor's letter, in which these words occur, is open to inspection by any interested person. Meanwhile, alongside my letter appeared letters from two other scientists, both containing favourable comment on the Soviet Union. Newspapers of nearly every shade of political opinion pour out praise for the U.S.S.R., but scarcely ever print even a mild adverse criticism of any aspect of the regime.* The same applies to the B.B.C. programmes: constant praise is allowed, never (so far as my listening experience goes) a single adverse word since the U.S.S.R. was forced into war.

When Germany invaded the U.S.S.R., that country and Britain were in a position which has points of resemblance to that of two strangers who are attacked by a maniac in the street. The proper thing is obviously to collaborate in every possible way to restrain him. It is no time for back-chat between the strangers as to details of their home lives. Far the best thing is for each person to help the other as much as he can. That would have been a desirable and healthy relationship between the two countries. Directly the U.S.S.R. was invaded, however, those who favour its political system saw that their chance had come, and propaganda began. Although British socialists believe in free elections and parliamentary government and many other institutions unknown in the U.S.S.R., yet on this occasion they did not resist the opportunity of praising a state which had put into practice certain of their own precepts. The public, which had been strongly anti-Soviet at the time of the war against Finland and when the U.S.S.R. made a pact with Germany, now began to change its mind. As more and more pro-Soviet propaganda poured forth and no answer was published * (except in obscure journals written in foreign languages), public opinion underwent a profound change. People began to believe that those who

* The *Spectator* is an exception to this statement. It has boldly upheld the principle of freedom of publication, so far as the censorship allows.

had criticized the U.S.S.R. were dishonest people who had given false information for their own private benefit. They now became anxious to receive more and more pro-Soviet propaganda, and were incensed against even a very feeble voice raised in protest. Those who had kept quiet about the virtues of the Soviet regime during the episodes of the Finnish war and Stalin's pact with Hitler now became vocal, and to the voice of genuine believers in totalitarianism were added those of demagogues who are always ready to tell the public what it wants to hear. Among those who praise the Soviet regime most loudly are people who only a few years ago attacked it in words which would be quite unprintable to-day*: and they give no public indication that they have changed their minds. The propaganda has increased in snowball fashion, the public demanding more and more praise and resenting ever more fiercely the slightest dissentient voice.

No scientist, except one who keeps his mind divided into watertight compartments and uses scientific method only in the laboratory, can view the present situation with equanimity. One side only is being heard, and every scientist knows that the truth cannot be attained in that way. The public acquiescence is a danger-signal. We need another Milton, a Hazlitt, a Bentham, or a Mill to remind us that Britain was formerly pre-eminent in the preservation of liberty of speech and publication. Nowadays those who love liberty have got to admit that it is the U.S.A., not Britain, that upholds their cause. It is unlikely that anything will change the government's decision on this matter while the war lasts, but scientists have a solemn duty to demand the restoration of freedom of speech and publication directly it ends.

Another political duty of scientists concerns the principles of valid argument. In a democracy, legislation depends ultimately on the opinion of the people as a whole. It is therefore desirable that they should form their opinions by considering valid arguments based on a truthful presentation

* I am ready to substantiate this statement directly the censorship is lifted.

of facts. It is my purpose to suggest that the scientist's love of truth could be harnessed to the common welfare of mankind, if he could persuade others to use his own method of argument in the political sphere.

Three kinds of people above all others are concerned with the fearless discovery and dissemination of truth. These are the philosopher, the historian, and the scientist. All three, if they wished, could use their influence to improve the standard of political discussion. The scientist, however, is likely to be able to influence the mass of humanity more easily than the philosopher or the historian, because people tend to suspect philosophy and ignore history, while trusting and respecting science. This is perhaps not very extraordinary. The differences of opinion between philosophers have always been more fundamental than those between scientists. Philosophers have not built up a body of generally accepted opinion at all comparable in magnitude with that built up by scientists. Although people do not often dispute with the historian, yet they do not see his actual evidence; and as a rule they are far more interested in the present and future than in the past. These remarks are not intended as a disparagement of philosophy and history, than which scarcely anything could be more absurd: they are only intended to suggest that the scientist can probably influence the opinion of the people more easily than the philosopher or historian. If all three groups of intellectuals would work together for the same end, so much the better.

Every scientist who reads the newspapers or listens to discussion knows that people try to influence political opinion in ways that would be universally condemned in his own sphere. Craftily misleading, confused, false, and sarcastic statements are made; facts are wilfully exaggerated or minimized; low motives are imputed without evidence; slogans are repeated; invective is used as a substitute for argument; hate is stirred up by the exhibition of hate; atrocities are condemned only when perpetrated by political opponents; the idea of truth as

an end in itself is derided. These methods are by no means confined to the popular press, but flourish also in political journals intended for intellectuals. The attempt to influence political opinion in this way reaches its culmination in the political cartoons printed in our newspapers. If one takes the trouble to write down in words the message conveyed by one of these cartoons, the falsity of the method of argument becomes apparent. It is strange but true that the publication of political cartoons is not confined to the most unintellectual newspapers. The scientist knows how he would feel if anyone tried to influence his opinion on a scientific matter by such obviously false methods, and he should press for the introduction of his own methods of argument into politics.

The cinematograph is nowadays being used to affect public opinion without regard for truth. People who are little influenced by print, because they read little, can be greatly influenced by what they see upon the screen; and the opinion of many people who do read is much more easily influenced by the cinema than by other methods of propaganda. Films making propaganda for a foreign political regime profess to be truthful, but in fact not only give a false general impression, but actually represent incidents which are known never to have occurred. The menace of cinematographic propaganda seems not to have been realized. Scientists should not be content to let people absorb falsehoods by the prostitution of a marvellous instrument which owes its existence to science. The falsehoods contained in films which profess to represent the truth should be exposed directly the censorship permits it. (The cinematograph is also being prostituted in another way. Our ancestors made public executions illegal. The cinema now undoes their wise and civilizing legislation.)

Three arguments have been brought against me when I have suggested in public that scientists should try to improve the standards of political controversy. The first is not very important. Public speaking and writing, it is said, would become weak and spineless if the suggestions were put into

practice. This is a misunderstanding. No objections can properly be raised to forcible wording, if the words contain no rhetorical device intended to affect opinion without the use of reason by the hearers or readers. Sentences may be decorated with metaphors, similes, and humour, as is sometimes done in scientific discussions, if the result is only to clarify and make vivid the meaning of what is being said and not to persuade others by subterfuge. Nothing can be urged against the straightforward condemnation of what is thought to be wrong, for if the speaker or writer expresses himself unequivocally, it is easy for him to be corrected when he makes a mistake (and we all make mistakes, in politics as well as in science).

The second criticism is serious. It is said that the common man neither uses nor wishes to use reason, and that therefore one should appeal only to his emotions. There is an inherent fallacy here, for the most reasonable man would be as lazy and unproductive as a pig if he were not inspired to action by emotion: both emotion and reason are necessary for reasonable action. There is no harm in seeking to arouse emotion in one's hearers or readers, if it is done only by a truthful presentation of the facts that have aroused the same emotion in oneself. Every successful science teacher does this in his lectures. The serious point is that the critics are willing that our democracy should be governed by the opinions of unreasonable people. Surely anyone who thinks that the common men of a democracy do not use reason should press urgently for the institution of anti-rhetoric classes in our elementary schools, instead of recommending that politicians should continue to use unsound arguments. It is questionable whether there is any greater single benefit that could be conferred on a democratic community than the teaching of the principles of reasonable argument in every school.

A third criticism made against the suggestion that only reasonable arguments should be used in politics is that, whereas the general welfare of scientists is little affected by the theories they discuss, politicians are concerned with

matters that deeply affect the day-to-day life of themselves and others. While the scientist naturally uses reason, it is argued, the politician rightly stirs up emotion by any available device. This argument is easily answered. The scientist uses reason in discussing his theories because he wishes to arrive at truth. In so far as the politician does not use reason, he does not wish to arrive at truth, but on the contrary intends to persuade people to accept and act upon untruth. He wishes, therefore, that the people should agree to legislation to which they would not have agreed if they had known the truth.

Famous research workers could use their great prestige to influence a wide public to demand higher standards in political controversy. Science masters at schools could exert a powerful influence for good if they were to suggest to their pupils that sound methods of argument are applicable in the discussion of matters affecting social life. Science students at universities could also be influential. They could attend the meetings of the political clubs of their universities, and methodically expose the illegitimate rhetorical devices used by the speakers. They could show what parts of the arguments were valid and of a kind that could reasonably affect opinion, and what parts were irrelevant. If that were done, the influence of those science students would spread far beyond their universities. Scientists of all kinds who want to make a special contribution to general welfare apart from the fulfilment of their primary duty would find here a congenial field of action.

It is, of course, far easier for the scientist than for the politician to use valid methods of argument, for the latter is subjected to severe temptations to put expediency before principle and to think of the desirability of the ends he seeks rather than of the justice of the means he uses to attain them. It may be true that on the average science attracts a higher type of man than politics, but if the scientist remembers his freedom from the difficulties that beset the politician, he will not lightly make the claim. Nevertheless, without any

unwarrantable self-satisfaction, the scientist may legitimately point out that in science we have a means of arriving at truth which we should be happy to share with others. It seems probable that the historian of the future will find it hard to understand how twentieth-century science can have co-existed with the methods now employed in political discussion. He is likely to ask why the twentieth-century scientist was content to let legislation depend on methods of argument so palpably false, without even suggesting that the state of affairs could be improved.

Scientists have another political responsibility beyond those of urging the necessity for free speech and trying to reform the methods of political argument. Science is international, and there is a duty towards the scientists of other lands. In totalitarian states scientists see their subject subverted by political issues, are deprived of liberty of speech and publication, and are subject to wrongful dismissal, imprisonment, exile, or execution (see, *e.g.*, V. V. Tchernavin).[100] The scientist's feeling of world citizenship should forbid him to remain aloof. Something has indeed been done for some of the scientists who have suffered under Nazi tyranny, but little attention has been paid to sufferers under other totalitarian regimes. When making propaganda for totalitarianism, British scientists have sometimes callously overlooked the persecution of their fellow-workers. This field for humane action will remain open until scientists throughout the world have freedom of speech, publication, and inquiry, and are no longer subject to dismissal or punishment on account of race, class, or political beliefs.

5. *The Intellectual and the Common Man*

There is one duty that the scientist shares with every other kind of intellectual.

Human life has dignity mainly because men and women exist, and have existed, who are exceptional in virtue or intellect. They have arisen from every class. Honour

should be accorded to these exceptional men and women, and to those who make an environment in home, school, or university in which genius and talent can develop and flourish.

Many people to-day think of progress as meaning one thing only, the improvement of the material conditions of the poorer members of the community. This is a limited outlook, for true progress means something more than material advancement. It means movement towards greater things in science, philosophy, art, music, literature, and all other branches of intellectual activity. That kind of progress is perfectly compatible with the securing of a square deal and a happy life for the common man, and conflict can only arise when the needs of the common man are made paramount.

The common man is very willing to throw his daily penny into the coffers of the newspaper proprietor who will tell him sufficiently regularly what an uncommonly fine fellow he is, and how paramount are his interests. He does not recognize the logical absurdity of the praise. He does not understand that, if he were in any way uncommon in virtue or talent, he would not belong to the group of people on whom the praise is bestowed. The false attachment of special virtue and talent to people who by definition do not possess them has become so widespread as to constitute a serious threat to civilization. People are beginning to cease honouring great men, and to honour instead the masses of humanity or the publicists who reiterate their praise.

It can never have entered the heads of J. S. Mill and the other great apostles of liberty that the very people who owe their liberty to them would seek to destroy the gift. Nevertheless, it seems that the common man has not an urgent desire for liberty of action, and is prepared to use the vote granted to him by liberal-minded people to destroy not only his own liberty, but that of uncommon people as well. It is impossible to imagine that the common man understands the conditions under which great work in science, philosophy, or music can be done: he is prepared and actively encouraged to

think that the only thing that matters is his own material welfare. Further, he is apt to think that he has only to hand over the control of the affairs of the nation to a central planner and his economic welfare will be assured. The central planner has told him so.

That way lies the eclipse of intellectual life. Every thoughtful person has a duty to strive to prevent it. Not a few intellectuals, however, are doing exactly the opposite. So acutely conscious are they that common men have their rights and legitimate aspirations, that they fail to recognize the imperative necessity to prevent the satisfaction of these rights and aspirations from interfering with those of uncommon men. If throughout the centuries we had only had common men, we should still be living like savages. Progress will be slow if the wants of common men are made paramount. Those intellectuals who ally themselves with the herd to act against the interests of uncommon men are guilty of intellectual treason.

6. *Duties towards Animals*

These, then, are kinds of services that scientists can render to society without impairment of their integrity: they can protect the heritage of science against those who would destroy it; they can extend the appreciation of science among a wider proportion of the community; they can facilitate the entry of suitable people of all classes into professional science; they can use their influence in favour of freedom of speech and urge better methods of political argument; they can serve the interests of their fellow-workers in totalitarian states; and they can use their influence against the idea that the interests of the common man are paramount. These are services to their fellow-men, but their potentiality for usefulness does not end there. As J. S. Mill [72] pointed out, the standard of morality should not be confined in its application to human beings, but should be secured, "so far as the nature of things admits, to the whole sentient creation."

The word *sentient* in this context presumably means conscious. Here a perplexity assails us. Everyone knows, more certainly than he knows anything else whatever, that he is conscious, but he can only infer that anyone else is. Similarly he can only infer, and never be certain, that the higher animals have consciousness. In so far, however, as he treats other human beings with consideration because he believes them to be conscious, he should also act kindly towards those animals about which he draws the same inference. No one who has studied the nervous system and reactions of a sea-anemone would be likely to think it possible to be "cruel" to such a lowly animal, lacking as it does any central nervous system or brain. One might as well think of cruelty to one's own intestines, which may be cut freely by the surgeon without the use of anæsthetics and without the feeling of pain, though they have a diffuse nervous system of their own which is capable of ordering some quite complex responses to stimuli. When, however, one studies the brains of some of the higher animals, particularly the higher Vertebrates, and notes their reactions to complex situations, one can only say that it seems very probable that they are conscious and capable of enjoyment and suffering. We are here on grounds not of certainty, but of that degree of probability which determines moral judgments.

The biologist knows far better than others what a remarkable resemblance there is between the nervous system of a higher Vertebrate and that of man, and how certain centres of the brains of both are regarded as pain centres. It therefore devolves upon him, more than on the man in the street, to encourage kindness to animals.

A distinguished physiologist (I think it was Professor J. B. S. Haldane, F.R.S.) has somewhere remarked that he has never known a good physiologist who was fond of shooting as a sport. It is, I believe, true that if people knew more about the nervous systems of animals, they would be less inclined to take up shooting for sport, on account of the suffering caused

to wounded mammals and birds. It is no good pressing for the abolition of shooting: that would only cause devotees of the sport and the business interests concerned to bring powerful influence to bear in the contrary direction. Education of the young is the only hopeful way of tackling the subject. The present situation is not satisfactory. Men are sent to prison for causing suffering to tame animals, but they are perfectly free to cause much more suffering to wild animals. The trapping of animals for their furs probably causes more suffering than shooting, and some of the methods used are made particularly painful by the necessity not to damage the skin. Here again it is useless to try direct opposition against a powerful industry and the vanity and thoughtlessness of women, many of whom would probably give up wearing furs if they had once seen a living fur-bearer held in a trap. Biological education is again the remedy, reinforced by a law insisting that every skin offered for sale should bear a label stating whether the animal was trapped or bred on a fur-farm.

The killing of animals for food has become much more humane in recent times, but the methods of castration and ovariotomy require investigation, especially the latter.

Although biologists bear a responsibility to educate the public in the matter of the treatment of animals generally, clearly they have a very special responsibility for the animals upon which their own work is performed. Although the housing arrangements for animals are excellent in some laboratories, yet this is by no means always true. The Universities Federation for Animal Welfare is to be congratulated on the steps that it is taking on behalf of laboratory animals. The Federation is compiling information on methods of housing, feeding, anæsthetizing, and killing.[105] The vexed question of vivisection is one on which the scientist cannot remain indifferent. The public probably does not realize that a large number of so-called vivisection experiments involve no more than changing the diet or making subcutaneous injections, and that the animal on which a major operation has been per-

formed under anæsthesia is often killed without being allowed to regain consciousness. It is a fact that physiology would be struck an almost mortal blow if vivisection were made illegal, and the influence on medicine (human and veterinary) would be disastrous. Nevertheless, scientists have a duty to exercise the utmost thoughtfulness on this subject. I believe that painful experiments are sometimes performed, of a kind that is extremely unlikely to give valuable new knowledge. The scientist should take a lot of trouble in planning his experiments so as to reduce pain to a minimum. Meanwhile it is a healthy sign that societies exist to protect animals against vivisection. It is probable, however, that some members of such societies have a rather distorted view of the subject. I have never come across a case in which a scientist practised vivisection because he found pleasure in cruelty.

A point worth mentioning in connexion with this subject is that invertebrate animals are not legally protected. It might be desirable to modify the law. Some of the invertebrates, such as the octopus and its allies, have astonishingly highly developed sensory and nervous systems. The redrafting of the law, however, would be very difficult.

7. *Conclusion*

The purpose of this chapter has been to suggest various ways in which the scientist may use his special knowledge, talents, and outlook to make the world a better place, apart from the fulfilment of his primary duty in research or teaching. None of the suggestions made involves any sacrifice of the spirit of science. During the last twelve years much has been said about the social responsibilities of scientists, but nearly all of it has been quite different from what has been said in this chapter. Scientists have been urged to regard their subject as existing solely for service to man's material wants, to press for the central planning of scientific research, and to ally themselves with political groups which advocate the central

planning of society in general. Scientists should not accept this advice, for three reasons:

First, science does not exist solely to serve man's material wants.

Secondly, any thoroughgoing scheme for the central planning of research would gravely damage science.

Thirdly, totalitarianism is precisely the form of government that is least in accord with scientific principles; for scientists accept the authority of no one and recognize the necessity for liberty.

These three clauses are the answers to the contrary arguments stated in Chapter I. The purpose of this book has been to give the reasons why these answers are valid, and to suggest social responsibilities that scientists can undertake without sacrifice of the ideals they ought to serve. By undertaking these responsibilities in addition to their primary duties, scientists can show the reality of their belief in the liberty, fraternity, and inequality of man.

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